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THE LUZON TRANSPORTATION & CONSTRUCTION Co. is organized at Sutton, Neb., to build an electric railway from Subig Bay to Manilla, a distance of about 25 miles through a mountain range; utilizing available water power for generating the current. Mr. J. H. Culver, of Sutton, Neb., is the President, and Mr. H. C. Hartley, of Lincoln, Neb., is the mechanical engineer. A contract for construction and supplies will be made this spring.

THE THUN-BERTHOUD TROLLEY RAILWAY, opened in 1899 in Switzerland, differed from all its predecessors in utilizing the roadbeds of existing lines of railways, built for and previously operated by steam locomotives. It is a single-track line, 24.8 miles long, and starts from Berthqud, or Bungdorf, a station on the Berne-Olten Railway. For about 4.3 miles it uses the Emmenthal Railway tracks; and crosses the Berne-Lucerne line at Konalfingen, and it reaches Thun by the Berne-Interlaken Railway. The electric energy is generated at Spiez by hydraulic power, and it employs triphase currents under a tension of 16,000 volts, reduced to 750 volts for direct feed. It is operated by six motor carriages of 32 tons empty, and ten trailers, for passengers; and freight is hauled on 60 ordinary cars with two electric motors. Electric traction was adopted on this line for purely economical reasons; as the annual cost of coal was 52,000 francs for 5 trains daily each way; with 10,000 francs more for each additional train. With electricity the same expenditure enabled them to run 10 passenger trains and two freight trains daily each way.

NEW STANDARD LOW-WATER REFERENCE planes for the Great Lakes, have been prepared by Maj. W. L. Fisk, Engineer Corps, U. S. A. These reference planes are for use in connection with the soundings on lake survey charts, and they are based upon the official records of the U. S. Lake Survey for 1860-1901. The elevations of the several low-water planes, expressed in feet above mean sea level at New York, are:

For all Lake Superior charts	600 ft.
" " " Michigan charts	578 "
" " " Huron charts.	578 "
" " " Erie charts	570 "
" " " Ontario charts	243 "

A chart has been issued showing these elevations for each three months in each year, from 1860 to 1901, inclusive. The soundings on all lake survey charts will be reduced to the planes as soon as possible.

THE GLACIAL FORMATIONS AND DRAINAGE features of the Erie and Ohio basins form the subject matter of Vol. XLI. of the Monograph Series of the U. S. Geological Survey: it is prepared by Mr. Frank Leverett, and is now in press. The contents define the boundaries of the several drifts, glacial lakes, etc., note the great variations in altitude, and attempt to determine the causes of the change of drainage in the past. The characteristics of the outwash and the glacial drainage are set forth; the great glacial lakes are taken up in order, and the soils are classified. Maps and plates illustrate the text.

THE TURBINE PASSENGER STEAMER "King Edward," has been plying for the past season on the Clyde, between Fairlie and Campbeltown. This boat is a screw steamer, 250 ft. long and 30 ft. beam, propelled by three shafts fitted with five Parson's screw propellers. Another vessel has been ordered by the same company from the Parson's Marine Steam Turbine Co.; the new vessel to be 270 ft. long and have 21-knot speed, instead of the 20½ knots made by the "King Edward." This latter vessel has been compared for efficiency and economy with the paddle-wheel steamer "Duchess of Hamilton," one of the most successful boats on the Clyde. The results are given as follows:

	"Duchess of Hamilton."	"King Edward."
Coal burned, tons	1,758	1,429
Total mileage, miles	15,004	12,116
Miles per ton of coal	8.87	8.47
Average speed, knots	16½	18½

AN ODESSA-NEW YORK STEAMSHIP LINE will commence business this month, with a combination of the Deutsche Levante and the Hamburg American lines. This direct line will run from New York to Odessa, touching at Malta, Alexandria, Constantinople, Novorossisk, Batum and Odessa. It will take the place of the lately-discontinued Barber Line, running from New York to Constantinople. The Deutsche Levante Line sends five steamers each month from Odessa to Hamburg; two of them being classed as express.

A NEW DRY-DOCK AT ST. JOHN, N. B., is proposed, and a committee appointed to visit American docks and recommend a plan, reports as follows: The dock to be built of wood, with concrete and granite entrance, with pumps that would empty the dock in 80 minutes. The dimensions would be, length on keel-blocks, 665 ft., including a 15-ft. recess at head of dock for the bows of ships; width of entrance at bottom, 75 ft., at top, 90 ft.; width of dock basin at coping, 140 ft.; width of dock on floor, 75 ft., and 83 ft. at top of keel-blocks; depth of water over floor at extreme low water, 10 ft., and 6 ft. over keel-blocks; depth over keel-blocks at extreme high water, 35 ft; dock to be so located that it can be extended 100 ft. A rough estimate of cost is $800,000.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the morning of Feb. 3 on the Illinois Central Ry. near Apple River, Ill. A stock train was run into by a following train; four stockmen, who were asleep on the first train, were killed, and three seriously injured.——A bad collision is reported to have occurred on the Seaboard Air Line south of Savannah, Ga., on Feb. 3. An extra freight running past its meeting point is supposed to have caused the wreck, being run into by a southbound vestibuled passenger train. Three men of the train crews are said to have been killed and a number of others injured.

A NEW YORK STATE ISSUE OF $10,000,000 of good-roads bonds is recommended by State Engineer and Surveyor Bond in his annual report. Mr. Bond proposes the issue of 3% bonds payable in 17 years, with provisions for an annual payment into a sinking fund by the state and counties, sufficient to meet both principal and interest within the 17 years, the state to pay one-half. The expenditure of this sum would build over 1,250 miles of improved macadam roads. The Good Roads Convention, in its late meeting at Albany, N. Y., in adopting this recommendation, voted to advocate an appropriation of $20,000,000 3% 17-year bonds; the state to pay half of this issue, the counties 35% and the towns 15% of the same. The passage of a state wide-tire bill—to take effect in two years—is also to be urged.

LEAD POISONING AT MILTON, MASS., has been reported on by the Massachusetts State Board of Health as follows:

The results of the examinations thus far made show 17 well-marked cases of lead poisoning, some of them very severe. Examinations of the water supplied to Milton show that it contains an excess of carbonic acid, which, acting upon the lead of the pipe, produces the poisonous carbonate of lead, a poison which slowly accumulates in the human body, with very serious results.

A NOTEWORTHY DECISION against the Elevated Railroad in New York city was handed down by the Appellate Division of the Supreme Court on Feb. 7, 1902. The case was an appeal taken by Mr. H. B. Auchincloss from a decision of the Special Term of the Supreme Court dismissing an action to recover damages from the owners of the Ninth Ave. elevated line for constructing and operating a third track on that line. The Appellate Division holds that the act of the Rapid Transit Commissioners in giving the New York Elevated Railroad Co. the right to construct and operate tracks in addition to the two originally authorized was unconstitutional, or rather that the section of the act of 1875 under which they granted this permit violates the constitution of the state. Justice Ingraham summarizes the conclusions of the Appellate Division thus:

I can see no escape, therefore, from the position that the construction of this additional track in Ninth Ave. opposite the plaintiff's premises was unauthorized, and that the plaintiff was entitled to an injunction restraining the defendants from the maintenance and operation of this track.

The third track herein referred to is a middle track used for the operation of express trains from 116th St. to Christopher St.; a very large part of the regular morning and evening traffic from the Harlem district to lower New York goes over these trains. If this decision of the Appellate Division should prove final it may be expected that considerable difficulties will arise in handling this traffic.

THE CHICAGO ELECTRIC RAILWAYS, which are now the source of so much trouble, due to failure to properly accommodate their traffic, have been investigated by Mr. Ellicott, the City Electrician, who reports that waste of power and insufficient terminal facilities are the main points for criticism. The waste of power is estimated at 33%, due to an insufficient return circuit composed of badly bonded rails, and it is stated that with a better return system the companies could both save money and furnish better service. Some sections of the down-town lines have no feeder connections, and the single trolley wire with capacity for supplying current to three cars is often called upon to supply current to eight or nine cars. "In the event of blockades for any length of time the entire downtown section is overloaded and the schedule time of the entire system thereby increased. It is absolutely impossible to operate any more cars or even the present ones under any better schedule until the abnormal loss of power (33%) has been corrected. It is obvious that the total number of cars which can be operated over a line is dependent on the capacity of the line at the point of greatest congestion." Mr. Ellicott is said to have found 600 miles of trolley lines on the West and North sides in which the rails are mainly depended on for the return circuit.

PROGRESS ON THE ALBULA TUNNEL, in Switzerland (Eng. News, Dec. 19, 1901), for the month of December, 1901, is reported as follows:

	North end, ft.	South end, ft.	Total, ft.
Heading (bottom):			
Total, end of December....	6,630	6,880	13,510
Advance during December.	607	477	1,084
Mean daily advance.....	19.5	15.5	35.0
Finished tunnel:			
Total, end of December....	4,430	3,050	7,480
Advance during December.	164	98	262
Material at face of heading.	Granite	Granite	....

The work was stopped for a total of three days during the month. The average number of men employed was 652 at the north end, 243 at the south end, a total of 895, of whom 529 were employed in the tunnel and 366 outside. The water flowing from the portals measured 62 gallons per sec. at the north end and 17 gallons per sec. at the south end. The rock at the north heading was more seamy than heretofore, requiring considerable masonry work. At the south end, after 215 ft. of shales, granite was again reached at sta. 65,50; no water was struck at the joint and the machine drilling was not interrupted.

A PROJECT FOR CONNECTING THE WATERS of the Orinoco, Amazon and La Plata River systems is to be considered at a conference to be held at Rio Janeiro within the coming year, according to a resolution adopted by the Pan-American Congress now in session in the City of Mexico. The purpose of the conference is to consider the practicability of opening communication for freight boats starting from the mouth of the Orinoco, in Venezuela, going down the Amazon River and its branches, and then down the Paraguay River to Buenos Ayres. While no one explorer has passed over this entire route, individual reports lead to the opinion that the line is feasible. The waters of the Orinoco and Amazon now unite through the River Casiquiari, and one of the branches of the Amazon flows within one-half mile of a river of the Paraguay basin. This latter is one of the upper affluents of the Madeira River, which nearly reaches the low, level plains drained by the La Plata system. As long ago as 1772 a canal was actually dug through at this point, large enough to take a six-oared boat.

THE NATIONAL BUREAU OF STANDARDS, by act of Congress of July 1, 1901, superseded the Office of Standard Weights and Measures, of the U. S. Treasury Department. The functions of the new bureau are as follows: The custody of the standards; comparison of standards used in scientific investigations, engineering, manufacture, commerce and educational institutions, with those adopted or recognized by the government; the construction of standards; the testing and calibration of standard measuring apparatus; the solution of problems arising in connection with standards; the determination of physical constants and properties of materials, when such data are of great importance in scientific or manufacturing interests, and can not be obtained elsewhere with sufficient accuracy. The bureau is authorized to act for the general government, any state or municipal government in the United States, any scientific society, educational institution, firm corporation or individual in the United States requiring the use of standards. Excepting for the general or state governments, a reasonable fee will be charged for this service. A suitable site for the buildings of the bureau has been selected in Washington, and it is expected that they will be ready for occupancy by Jan. 1, 1903. Mr. S. W. Stratton is the Director, and further information will be given by him.

THE TRIANGULATION FOR BRIDGE NO. 4 ACROSS THE EAST RIVER, NEW YORK CITY.

By Oscar Erlandsen, M. Am. Soc. C. E.*

Surveys for the bridge over the East River, between the Boroughs of Manhattan and Queens, better known as the Blackwell's Island Bridge, or as East River Bridge No. 4, were commenced early in 1900 by the Department of Bridges. This bridge will be of cantilever design, and will consist of a cantilever span of 1,131 ft. over the west channel, a cantilever span of 984 ft. over the east channel, a fixed span of 630 ft. over Blackwell's Island, an anchor span of 469.5 ft. in Manhattan and an anchor span of 459 ft. on the Queens side, making a total length of 3,673.5 ft. c. to c. of anchor piers. The distances across both channels were obtained by triangulation from a measured base line. In the prosecution of this work novel methods were introduced and special apparatus was devised with the object of decreasing the time required without decreasing the degree of precision. This object was attained in so marked a degree as to seem to render desirable a record of the apparatus, methods and results.

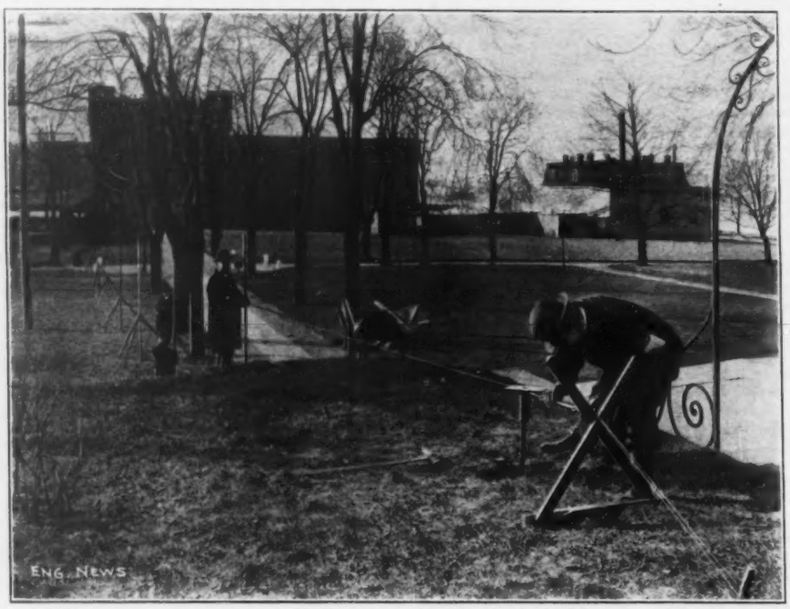

FIG. 1. VIEW SHOWING METHOD OF SUPPORTING AND READING TAPE IN MEASURING THE BASE LINE OF THE TRIANGULATION OF BRIDGE NO. 4, ACROSS THE EAST RIVER, NEW YORK CITY.

In the location of the base line and check base, a rather unusual plan was adopted. Both were located on Blackwell's Island, simply because there was no other place in the vicinity of the bridge site sufficiently free from obstructions. The base line and check base were in fact parts of the same straight line, the longer part, lying to the north of the center line of the bridge being the base line and the shorter part, that lying to the south of the base line, being the check base. The ends of the base and check base were marked by monuments, three in all. These monuments are of granite, 12 ins. square by 3 ft. long, dressed on top. In the top of each is sunk a square brass plate, on the underside of which is a lug ¾-in. in diameter and 6 ins. long, split at the lower end to receive a wedge. The lug is set in cement in a hole in the top of the monument and then driven down on the wedge. A small hole drilled in the brass plate marks the line.

In conformity with recent practice, the base and check base were measured with a long steel tape, supported at regular intervals. The points of support were, however, not level, nor were they on a continuous grade for the entire length of the base line or even for any considerable portion of it. For each separate measurement with the tape the points of support were on a true grade, but this grade was not necessarily the same for any two consecutive tape lengths. Moreover, the points of support were only temporary, and were set up anew for each measurement. To meet the requirements of supports that could be readily set up and adjusted to any grade the apparatus shown in Fig. 1 was devised.

The tape used was a steel ribbon ⅛-in. wide, 1-40-in. thick and 200 ft. long. It was compared once with the U. S. Standard at Washington, and twice with the N. Y. Standard at Albany. In all three comparisons the tape was supported for its entire length. At Washington the comparison was made in lengths of 100 ft., at Albany in lengths of 50 ft. The results varied considerably. The Washington comparison, made at a temperature of 50° F., with a pull of 10 lbs., made the tape 0.30-in. too long at the standard temperature of 62° F., while the Albany comparisons, the first made at a temperature of 65° F. under a pull of 11 lbs., the second at a temperature of 48° F. with a pull of 10 lbs., both made the tape correct at the standard temperature. A comparison was also made with a tape 100 ft. long, which was standardized in Washington in 1897, which showed an exact agreement between the two Washington comparisons made four years apart on different tapes. The Albany comparisons, made one year apart on the same tape, not only differed from the Washington comparison, but differed from each other. In view of the impracticability of reconciling these differences, the tape was assumed to be correct at the standard temperature under a pull of 11 lbs., if supported throughout, or 12½ lbs. if supported at intervals of 25 ft. This made it agree with the first Albany comparison, with two other tapes in use on the work and with the standards in use in other departments. The tape was provided at one end with the usual spring balance, and also with a turnbuckle for the regulation of the tension. It was supported at intervals of 25 ft.

The intermediate supports, Fig. 2, consisted of wooden rods 1 in. thick by 2 ins. wide. Along the entire center line of each rod was a line of holes ½-in. apart. Each rod was shod with a steel point. When in use this point rested on a tack driven on line in a stake. Each rod was held plumb and in place by means of a special extension leg tripod, the head of which is provided with two pairs of opposing thumbscrews. Pegs were placed in the holes in the rods on the grade of the end supports, the position of each being determined by eye by sighting over the end supports. The holes in the rods being ½-in. apart, each point of support is within a quarter of an inch of the true grade.

To each end of the tape was attached a piece of light-weight plumbers' brass chain, which passed over the end support to a pin driven into the ground, Fig. 1. The end supports were adjustable wooden crotches. Along the center line of each of the two pieces forming the crotch is a line of holes which, with a small bolt, provide for the adjustment of the crotch at any desired height. To make a rigid frame of the crotch the lower ends are hinged to a connecting bar.

The end of each measurement was marked on an adjustable table specially designed for the purpose, Fig. 3. Its top is a steel plate 6 ins. square, on the upper side of which is pasted a sheet of paper on which the end of the measurement is marked with a sharp pencil. On the lower side of the plate is a hollow cylindrical lug which fits over the top of an iron bar. A thumbscrew in the lug permits of clamping the table on the bar, at just the right height. Where the ground permitted, the bar was driven into the ground approximately to the required height. In other cases it was set in a heavy cast-iron base and clamped.

The base and check base were measured four times. The work was done during the morning in December, 1900, when the temperature was about at the freezing point, and took only four hours each time. The temperature was recorded for each 200 ft. The greatest range for any one day was only 5° F. The results obtained, reduced for grade and temperature, were: 1671.030 ft., 1671.028 ft., 1671.028 ft., and 1671.000 ft., for the total length of both bases. The fourth measurement was discarded because high winds prevailed while it was being made. The average was assumed at 1671.03 ft., of which the base line formed 1122.05 ft., and the check base 548.98 ft.

The angles of the triangles were measured with a Brandis transit having a graduated circle 8 ins. in diameter, reading by vernier to 10 seconds. In order to surmount various obstacles it was necessary to build towers about 12 ft. high at the ends of the base line. These towers were made double, the inner tower for the instrument, the outer for the observer, Fig. 3. A long square wooden pipe reaching from the floor of the inner tower almost to the ground, protected the plumb bob string from the wind. There were four tri-

Fig. 2. Enlarged View of Intermediate Support for Tape, East River Bridge Triangulation.

angles in all, Fig. 4, one on the base line for each channel and one on the check base for each channel.

Each angle of the four triangles was read ten separate and distinct times, with ten repetitions each time, reading continuously around the graduated circle, or in all, one hundred repetitions for each angle. The sum of the ten totals was divided by one hundred. The variation from 180° of the sum of the observed angles in each of the four

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triangles was, respectively: 0.1, 0.35, 2.7 and 4.9 seconds. These are so small that they do not affect the required length.

The targets used were boards 4 ins. wide and 8 ft. long, on the face of which was painted a series of white diamonds on a black field. The lower end of the target was shod with metal terminating in a sharp point, which was set exactly on line. These targets were held in place by means of the extension leg tripods previously described. They were set by means of a plumb bob hung from the upper end in an opening

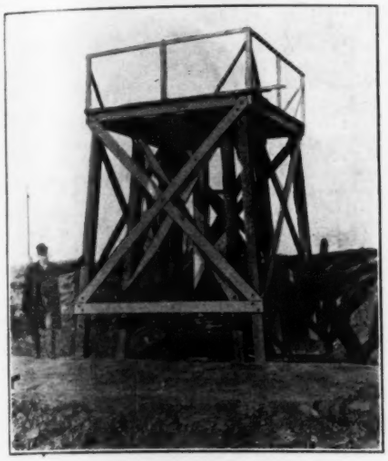

Fig. 3. Towers at End of Base Line for Triangulation of East River Bridge No. 4.

near the bottom, like that in a mason's plumb rule.

The distances across the west and east channels were found to be 1401.793 ft. and 1258.033 ft., respectively. From these distances the length of the check base was found to be: 548.977 ft. and 548.991 ft. The length obtained by actual measurement was 548.980 ft.

The work described was under the immediate charge of, and the apparatus was designed by, Mr. R. R. Crowell, Assistant Engineer Department of Bridges, City of New York, the writer being Assistant Engineer in Charge, and Mr. R. S. Buck, M. Am. Soc. C. E., Chief Engineer in Charge.

THE NEW YORK RAPID TRANSIT RAILWAY.

III.

Contract and Specifications.

The formal contract between Mr. John B. McDonald and the Board of Rapid Transit Railroad Commissioners, acting in behalf of the city of New York, provided (1) that the contractor should fully construct and equip the Rapid Transit Railway upon the routes and according to the general plans laid down by the Commissioners, and (2) that the contractor should after construction put the railway in operation and thereafter use, maintain and operate it under lease from the city for a period of 50 years. The contract, therefore, was divided into two sections, entitled, respectively, "Agreement for Construction" and "Lease." These titles will be retained in the following summary of the contract:

AGREEMENT FOR CONSTRUCTION.—Concisely described, the agreement for construction provided that the contractor should, in strict conformity with the specifications, construct the railway,

including therein the stations, side tracks, switches, cross-overs, terminal yards, and all other appurtenances complete and ready for operation, and including also all necessary construction of sewers along or off the route of the railway, all necessary readjustment of the mains, pipes, tubes, conduits, subways or other subsurface structures, the support and care, including underpinning wherever necessary, of all buildings of whatever nature, monuments, elevated and surface railways, affected by or interfered with during construction, and the reconstruction of street pavements and surfaces,

and should provide a complete equipment of the road according to the specifications.

Provision was also made that the Commission might during construction amplify the plans and specifications; that the acceptance of any part of the work or materials did not relieve the contractor from the obligation to furnish sound material and good work; that any dispute of the engineer's valuation of extra work and material was to be submitted to arbitration; that the entire period allowed for constructing the road should not exceed 4½ years; that the city should acquire the real estate for terminals and stations and charge the cost of it against the contractor; that payments for work done should be made not oftener than once a month, and then only upon satisfactory evidence and vouchers; that the contractor should be financially and personally responsible for all accidents to persons and property. The specifications referred to in these general provisions are in abstract as follows:

GENERAL METHOD OF CONSTRUCTION.—Two general methods of construction are allowed, namely, open-cut excavation and tunneling. Beginning at the City Hall loop those portions of the line along Center St., Lafayette Place, Fourth Ave., 42d St., and Broadway (between 42d and 60th Sts.), were to be open-cut excavation. No opening, unless roofed over with timber so as to permit the passage of vehicles and pedestrians, was to exceed in length 400 ft., or in width the distance to the center of the street, or the outer rail of the car track next beyond the center of the street, plus such reasonable space in addition as might be required for sheathing; the balance of the width of the street was to be left unobstructed for normal surface traffic. No two unroofed openings were to be within 500 ft. in the clear of each other, and at every cross street the opening was to be crossed by a bridge having a 15-ft. roadway and a 5-ft. sidewalk, except at 14th St., 23d St., and Fifth and Sixth Aves., where the bridges were to have a 30-ft. roadway and two 5-ft. sidewalks. No open excavation was to be maintained in front of any property for a period greater than 30 days, unless by consent of the property owner. For that portion of the route along Elm St, open-cut excavation the full width of the street was permitted, on condition that street crossings were bridged and that no more than two city blocks were closed at one time in one length of cut. For that portion of the route under Park Ave., between 33d and 40th Sts., the work was to be done by tunneling without disturbing the surface. Tunneling was also required on that portion of the route from 104th St. under Central Park to about Lenox Ave., and was permitted on other portions of the route which the contractor might desire to work in that way. For that portion of the route lying beneath the Harlem River and the approaches thereto, the work was to be conducted by means of compressed air, dredging, open caissons founded on piles, or such other means as the contractor might prefer and the engineer approve, but it was to be so conducted as to give the tunnel a firm foundation without danger of settlement and to leave during construction a clear waterway of 200 ft. For all other portions of the route north of 60th St., the contractor was given permission to conduct his work in the most expeditious manner possible, having due regard to safety of persons and property and reasonable considerations for the accommodation of street traffic.

EXCAVATION.—Wherever work was carried on by open excavation access was to be ensured to hydrants, fire-alarm boxes and to buildings for purposes of fighting fire. Such excavated material as might be suitable for mortar or concrete could be stored on the ground, but all other excavated material was to be removed expeditiously, the carting away to be done between 7 a.m. and 8 p.m. Temporary tramways on the streets for handling excavated material were permitted subject to immediate removal upon the order of the engineer. All carts, buckets, and vehicles for handling excavated material were to be tight and so arranged as not to spill over the top. All open excavations were to be properly secured against caving by suitable sheathing. In the event of encountering quicksand, subsurface streams, or similar dangerous conditions, or where passing especially heavy buildings, which by their construction or position might bring a great pressure on the trenches, the right was reserved by the engineer to direct that but a short length of trench be opened at one time, and, furthermore, to direct, if necessary, that this trench be sheathed securely and braced on all sides after the manner of a shaft, and that the permanent work be constructed in this shaft, and backfilled before another opening was made. Where pumping was necessary it was required that it be done in such a manner as not to disturb or remove the particles of soil. Wherever blasting was necessary it was required that all blasts were to be covered with logs, and further as follows:

Explosives shall be used only of such character and strength as may be permitted by the Board; and the right is reserved for the engineer to direct that in special cases ordinary blasting powder only, in small charges, shall be used. Wherever any pipe or main is encountered in the trench, right is reserved to direct that all rock within 5 ft. of the same shall be removed by means other than blasting. In residential districts no blasts in open trenches shall be fired, without the special permission of the Board, between the hours of 8 p.m. and 7 a.m. No larger quantity of explosives shall be kept on the line of the work than will be actually required for the 12 hours of work next ensuing, and such supplies shall be divided as far as possible and kept under lock, the key to which is only in the hands of the foreman or other equally trustworthy person. The amount of explosives kept in any one place shall not exceed the limit permitted by any ordinance of the city, or as may be determined by the Board. Caps and exploders shall not be kept in the same place with dynamite and other explosives. During freezing weather special precautions shall be taken as to the care and manipulation of dynamite.

BACKFILLING.—The excavation at the sides and over the top of the tunnel were to be backfilled with sand, gravel or good clean earth free from stones exceeding 8 ins. in diameter, and not containing of stones below this size more than one part to three parts of earth. This filling was to be deposited in 9-in. layers packed by rammers weighing not less than 30 lbs. No frozen earth was to be used.

PILE AND TIMBER FOUNDATIONS.—In wet ground of such character as to require piling, the piles used were to be of oak, pine or spruce, 12 ins. in diameter at the butt and 6 ins. in diameter at the point.

TUNNELING.—All tunnels were to be lined with concrete or brick masonry. In dry rock free from water-bearing seams, the lining was to be of brick or concrete, at the option of the contractor; in wet ground the lining was to be of brick, of which at least one ring in the arch and one brick thickness in the side walls was to be laid in asphalt. All spaces between the lining and the excavated profile were to be packed with dry stone or with rubble masonry. When dry packing was used the top of the arch and the backs of the side walls were to be plastered with 1 to 1 cement and sand mortar ½-in thick.

CEMENT.—Natural and Portland cements equal in quality to the best grades of Rosendale cement and American Portland cement were to be used. All cements were to be subject to inspection and such tests as the engineer should require. Cements were to be stored in tight buildings, each cask or package being raised several inches above the ground by blocking or otherwise.

MORTAR.—All mortar was to be made of cement in perfect condition and sharp clean sand. These ingredients were to be thoroughly mixed dry and water then added in sufficient quantities to produce a thick paste.

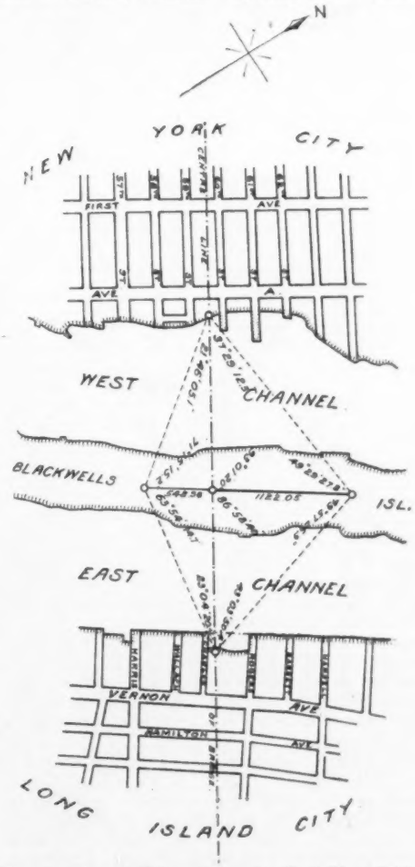

Fig. 4. Plan of Triangulation for East River Bridge No. 4.

No mortar was to be used that had taken an initial set and retempering of mortar was permitted under no circumstances. The proportions of mortar by volume were to be for the various classes of work as follows:

Brick masonry: 1 portion of Portland cement and 2 portions of sand.

Column footing stones: 1 portion Portland cement and 2 portions sand.

Stone masonry: 1 portion Portland cement and 2½ portions of sand.

Rubble masonry: 1 portion natural cement and 2 portions sand.

Pointing: 1 portion Portland cement and 1 portion sand.

CONCRETE.—The requirements for concrete were as follows:

The concrete shall be composed of sound, clean, screened gravel or sound broken stone, or a mixture of both, free from all dirt and dust, and mixed together with the proportion of mortar specified below. The broken stone or gravel used for concrete for the finishing floor of the railway, must not exceed 1 in. at their largest diameter. For all other concrete the maximum diameter for broken stone or gravel, unless specifically permitted by the engineer, must not exceed in any direction 2 ins., with a minimum diameter of ¼-in. In all concrete where the thickness is 30 ins. or more, the contractor may imbed in the same broken pieces of sound stone whose greatest diameter does not exceed 12 ins. and whose least diameter or thickness is not less than ¾ the greatest diameter. These stones shall be set by hand in the concrete as the layers are being rammed, and so placed that each stone is completely and perfectly bedded. No two stones are to be within 6 ins. of each other and no stones within 4 ins. of an exposed face.

The proportions of mortar and stone used in making concrete shall be as follows: Concrete in arches of roof and side walls, where the thickness does not exceed 18 ins., 1 portion Portland cement, 2 portions sand, 4 portions stone. Concrete in side walls or tunnel arches, where backing is rock in place, 1 portion Portland cement, 2½ portions sand and 5 portions stone. Concrete in foundations in wet ground, where thickness, exclusive of finishing floor concrete, does not exceed 24 ins., 1 portion Portland cement, 2 portions sand, 4 portions stone. Concrete in foundations in wet ground where thickness, exclusive of finishing floor concrete, exceeds 24 ins., 1 portion Portland cement, 2½ portions sand, 5 portions stone. Concrete in foundations in dry ground, 1 portion Portland cement, 2½ portions sand, 5 portions stone. Concrete in foundations where on rock, if not exceeding 12 ins. in thickness, 1 portion Portland cement, 2½ portions sand, 5 portions broken stone; if exceeding 12 ins., 1 portion Portland cement, 3 portions sand, 6 portions broken stone.

(Note.—If the rock is dry, natural cement may be substituted for Portland cement in above, but increasing the quantity of cement used 30%.) Concrete in mass, such as retaining walls, or backing of masonry retaining walls, in dry ground, 1 portion natural cement, 2½ portions sand, 5 portions stone. If such retaining walls or backing are in wet ground, or subject to extraordinary strain, then Portland cement shall be substituted for natural.

The broken stone or gravel shall be spread on a platform sprinkled with water, and then thoroughly mixed with the mortar in the proportions as specified above. Machinery for the mixing of concrete may be used if approved by the engineer. The concrete shall be laid immediately after mixing and be thoroughly compacted throughout the mass by ramming. The amount of water used in making the concrete shall be approved by the engineer. The concrete shall be allowed to set for 12 hours, or more, if so directed, before any work shall be laid upon it; and no walking over or working upon it shall be allowed while it is setting. Before laying concrete on rock surfaces the latter shall be swept clean of all debris and dirt. Whenever it becomes necessary to lay fresh concrete next to or on top of concrete in which the mortar has already set, the surface of the old concrete shall be well washed, and a thin layer of clear cement shall then be spread over it immediately previous to the laying of the fresh concrete. Suitable molds shall be provided by the contractor to support the concrete while being rammed in the walls or roofs. These molds shall be immediately replaced by new ones as soon as they commence to lose their proper shape. Before being used they shall be carefully cleaned of cement and dirt and shall present to the concrete on the surface afterwards exposed to sight a perfectly smooth surface, to be obtained by covering such portion of the molds with sheet metal, or by carefully planing the wood and coating the face of the same with black oil. In no case on an exposed surface of the concrete must the joints of any component pieces of the mold, nor the grain of the wood, be visible. The molds shall be set true to line, firmly secured, and be so tight as not to allow water in the mortar to escape. They shall remain in place until the concrete is thoroughly set, and in event of pressure coming at once on the concrete, such additional time as the engineer may direct. On removing the molds, if any voids or irregular conections with the steel framework are discovered, such defective work shall be cut out and filled with a rich concrete or mortar, in such proportions and in such manner as the engineer may direct.

BRICK AND STONE MASONRY.—The requirements for brick and stone masonry were such as are usual to first-class work of this sort in all high class engineering structures.

WATERPROOFING.—One of the most important clauses of the specifications was that relating to waterproofing, and this clause was, in full, as follows:

It is the very essence of these specifications to secure a railway structure where underground, which shall be entirely free from the percolation of ground or outside water, to which end construction shall be carried out as follows:

After the soil has been excavated to the required depth, and dressed off to a true grade as directed by the engineer, there shall be laid a bed of concrete of the proportion as herein described, of such thickness as the local conditions demand, in the judgment of the engineer. On such bed, which shall be made as level and smooth as possible on the top surface, there shall be spread a layer of hot asphalt, and on such asphalt there shall be immediately laid sheets or rolls of felt, all of the quality hereinafter described; another layer of hot asphalt shall be spread over the felt; another layer of felt laid, and so on until not less than two such layers of felt nor more than six be laid with asphalt between each layer, and below and on top. On top of the upper surface of asphalt, the remainder of the concrete, as called for by the contract drawings, shall be put in place. In dry, open soil the felt in the floor concrete may be omitted, the base course of concrete being covered with one good layer of asphalt. In rock excavation, where the same is dry and above water level, both the felt and the asphalt in the floor may be omitted.

When the I-beam columns of the side walls are set and secured permanently in place, the concrete composing the side walls shall be rammed in place in such manner that the back or outer face is flush with the outer flanges of the columns. On such outer face hot asphalt shall be brushed and felt spread in alternate layers, in the manner as described for the foundations, and the backing of concrete then added as shown by the plans. Instead of constructing the side walls with the waterproofing, as described above, the contractor may build in dry, open soils, if permitted by the engineer, and if no additional width of excavation is required for sewers or other purposes, a 4-in. brick wall supported at the back by the trench sheathing, laid in cement mortar or hot asphalt, and at a distance of at least 2 ins. in the clear from the line of the exterior faces of the side-wall beams, and to attach to it the layers of waterproofing material as described above, and then to ram around the beams and against the waterproofing surface the concrete composing the side walls. Under similar conditions in dry rock excavation, the rock may be excavated so that no projecting point comes within 3 ins. of the line of the exterior face of the side-wall beams; and then the rough surface shall be made smooth with a plaster of concrete, and on such smooth surface the waterproofing material shall be spread, and then the concrete of the side walls rammed against the same in the manner as described above.

The roof of the structure shall be treated in a similar manner by finishing the jack arches to such a height as directed by the engineer, spreading the asphalt and felt in alternate layers and then adding a cover of concrete, completing the roof as called for by the contract drawings.

By the arrangement above described there will be a continuous sheet of asphalt and felt embedded within the concrete of the bottom, top and both sides, and completely enveloping the structure.

The asphalt used shall be the best grade of Bermudez, Alcatraz or Lake asphalt, of equal quality, and shall comply with the following requirements: The asphalt shall be a natural asphalt or a mixture of natural asphalts, containing in its refined state not less than 95% of natural bitumen soluble in rectified carbon bisulphide or in chloroform. The remaining ingredients shall be such as not to exert an injurious effect on the work. Not less than two-thirds of the total bitumen shall be soluble in petroleum naphtha of 70° Baume or in Acetone. The asphalt shall not lose more than 4% of its weight when maintained for ten hours at a temperature of 300° F.

The use of coal-tar, so-called artificial asphalts, or other products susceptible to injury from the action of water, will not be permitted on any portion of the work, or in any mixtures to be used.

The felt used in waterproofing such part of the structure as is below ground water level shall be composed of asbestos or other equally non-perishable material dipped in asphalt and weighing not less than 10 lbs. to the square of 100 ft. The felt used in other parts of the structure shall be the same as the above, or of the best quality of coal-tar felt weighing not less than 15 lbs. to the square of 100 ft., except, that if the latter be used, one layer more will be required than of the former. All felt shall be subject to the apprvoal of the engineer.

The surfaces to be waterproofed shall be smooth, without projecting stones, or made smooth where necessary by a coating of mortar of 1 portion natural cement to 1 portion sand, and should be dry before the asphalt is applied.

Means for artificially drying the surface of concrete may be taken by the contractor by blowing warm air over it, or as otherwise permitted by the engineer, but not until the concrete has had at least 48 hours to set.

Each layer of asphalt fluxed as directed by the engineer must completely and entirely cover the surface on which it is spread without cracks or blowholes.

The felt must be rolled out into the asphalt while the latter is still hot, and pressed against it so as to insure its being completely stuck to the asphalt over its entire surface, great care being taken that all joints in the felt are well broken, and that the ends of the rolls of the bottom layer are carried up on the inside of the layers on the sides, and those of the roof down on the outside of the layers on the sides so as to secure a full lap of at least 3 ft.

Especial care must be taken with this detail. None but competent men, especially skilled in work of this kind, shall be employed to lay asphalt and felt.

When the finishing layer of concrete is laid over or next to the waterproofing material, care must be taken not to break, tear or injure in any way the outer surface of the asphalt.

The number of layers of felt on the sides and under the floor shall in no case be less than two in ground that is quite dry, and where there is a water pressure against the masonry equal to 12 ft. not less than six layers. Where the water pressure is less than 12 ft., or where the ground is damp, such number of layers between three and six shall be used as the engineer may direct. The number of layers of felt on the roof shall not be less than three of asphalted asbestos or four of tarred felt.

At any point where the contract drawings and the engineer permits, the contractor may lay, instead of the asphalt and felt above described, one or more courses of bricks dipped in hot asphalt of the above described quality, and laid while the coating of asphalt is still hot.

In foundations the contractor may lay, if he prefers, instead of the ordinary concrete with the layer of waterproofing material, as above described, a bed of asphaltic concrete, composed of broken stone of the qualities previously described for concrete, heated in a suitable heater to such proper temperature as the engineer may direct, and when so heated have added thereto the melted asphalt of the quality described above, and in such proportion as to ensure a covering of each particle of stone with asphalt, and the whole mass shall then be thoroughly mixed and incorporated in a suitable mixer. Such asphaltic concrete shall be spread in place and thoroughly rolled and compressed so that it will present a smooth, even surface, that will be impervious to water. No asphalt shall be heated to exceed a temperature of 325° F.

In masonry-lined structures, where there is no steel work and the ground is dry, the regular waterproofing may be omitted, but in that case, in arched cut and cover work, the extrados of the arch shall be coated with hot asphalt of the quality described or the best grade of refined Trinidad.

Any masonry that is found to leak at any time prior to the completion of this work shall be cut out and the leak stopped, if so ordered by the engineer.

DRAINAGE.—Every part of the railway was to be so arranged that any water finding access thereto would be led away automatically to the city sewers. Where the underground portion of the road was on an inclined gradient and was constructed in dry, porous soil, the floor might be depended upon to act as a conduit. At the bottom of the inclined gradient connections were to be made with a sewer or with subdrains lying beneath the railway and draining into the sewers. Where the soil was not porous or where the floor of the road could not be used as a conduit, there were to be laid beneath the rail level drain pipes of salt-glazed stoneware, one for each two tracks, not exceeding 12 ins. in diameter each. Each drain was to be laid on the concrete or directly in the soil with closed or open joints. In rock excavation or in tunnel, drains formed of broken stone or tile were to be set at every seam or fissure bearing water. These drains were to be built outside the side walls of the railway, connected with the main drains, and so arranged as to lead the water into the sewers. Wherever the grade of the railway passed below the bottom of adjacent sewers there was to be constructed a sump of not less than [illegible] gallons capacity. At every sump there was to be an electric or other improved pump with a capacity of 400 gallons per minute against a head of 15 ft., arranged to work automatically.

STEEL AND IRON.—Two grades of steel, designated as medium steel and rivet steel, were to be used. All steel was to be made by the open-hearth process and might be either acid or basic with the following maximum limits of phosphorous:

Grade.	Acid.	Basic
Medium steel	0.06%	0.04%
Rivet steel	0.06%	0.04%

Test pieces were to fulfil the following requirements:

Grade.	Ultimate strength, lbs.	Elastic limit, lbs.	Elongation.	Reduction.
Medium steel	58,000 to 66,000	33,000	20%	44%
Rivet steel	50,000 to 58,000	28,000	27%	54%

The other test requirements were such as are required of all first-class bridge steel.

PAINTING.—All metal work was to receive one coat of red lead paint before leaving the shop, and after erection two coats of paint of such color as was chosen by the engineer. The surface of concrete and brick walls and roof arches were to be plastered or painted with three coats of a light color. At stations the final coat of paint was to contain such a proportion of granulated cork as the engineer should direct.

SUBSIDIARY WORKS.—The construction of the subway required the rebuilding of sewers and water mains, and the repaving of streets. Complete specifications for each of these kinds of work were prepared to conform to the standards of good practice in America.

STATIONS.—Stations were to be of two kinds, one for local trains only, and one for both local and express trains, and were to conform to plans prepared by the engineer or prepared by the contractor and approved by the engineer.

The roof of the stations, where under the sidewalks, shall, to as great an extent as possible, consist of what are known as vault lights. These lights shall be made of cast-iron frames, with lenses not exceeding 2 ins. in diameter, of strong glass set in cement, all of design approved by the engineer; which frames shall be of sufficient strength to carry, when supported in a manner similar to that in which they are to be permanently set, an equally distributed load of at least 500 lbs. per sq. ft. without signs of failure, deformation or permanent set when such test load is removed. The right is reserved to test at least one frame in every ten delivered, as selected by the engineer. Should the one selected fail, another will be selected by the engineer; and, if that fail, then the whole lot may be rejected. These frames must be set in place with cement, lead or other means to be absolutely waterproof, as tested by a hose with ½-in. nozzle and hydrant pressure.

In order to prevent any leaks and as far as possible condensation, the contractor must exercise great care in the construction of station walls and roofs. The walls above the platform level, when acting as retaining walls, shall be built of brick or concrete with a waterproof layer, all as described under the appropriate clauses in these specifications. The walls shall be faced with enamelled hollow bricks. If such hollow bricks cannot be obtained of quality satisfactory to the engineer, then at a distance of 1 in. from the interior face of such walls, there shall be built a wall of enamelled bricks, or in place of enamelled bricks a wall not less than 4 ins. thick of hollow brick, the exterior face of which shall be covered with enamelled tiles. The interior wall may be stayed by header bricks abutting against the main wall, such header bricks occurring not oftener than one in each square yard. The hollow spaces in the walls shall be connected at the bottom by a pipe furnished with a stopcock and leading to the drain.

The floors of stations shall be of some approved form of cement or artificial stone, and shall be so arranged as to drain to one or more points, as directed, where suitable and proper provision shall be made for the removal of water used in flushing the same. In the designs of stations all corners formed by intersecting walls shall be avoided by joining these walls by curves of large radius. In order that such curved surface shall present a smooth and workmanlike finish, the contractor shall supply special bricks or tiles properly curved to the radius used; and where the side walls join the floor the corners shall be rounded by specially made bricks or tiles curved to a radius of at least 2 ins. All details of the stations must be so arranged as to facilitate cleaning, and to permit if desired a thorough washing of all parts of the stations and their approaches by means of a hose.

The ceilings of stations where not made by vault lights shall be made as follows: The roof shall be formed in the ordinary manner as the roof of the railway; that is, of brick or concrete jack arches, all carefully waterproofed. The interior surface shall be made of wood, plaster on expanded metal laths, or some non-conducting material approved by the Board. This material, of whatever nature, shall be of the best quality ordinarily used for such purpose, and shall be attached to the flanges of the roof beams so as to leave an air space behind the same. The ceiling on the exposed surface shall be suitably decorated. The stairways shall be of iron or of sound and suitable stone, and furnished with the most approved form of treads to prevent slipping. Wherever possible there shall be two stairways for each side of each station, and all stairways shall be of as great a width as the local conditions will satisfactorily permit and as the Board may approve. Where the presence of areaways or other openings permit there shall be louvre ventilators of glass of approved design placed immediately beneath the ceiling of stations. These louvres shall be in height not exceeding 3 ft., shall extend in length as great a distance as the local circumstances shall permit, unless otherwise ordered by the Board, and shall be so arranged as to exclude storm water. The ticket booths, railings, doors and other details are to be of wood, brass and glass, and designed

and constructed with skill and in a manner approved by the Board.

LEASE.—According to the terms of the lease, the contractor agrees to equip, maintain and operate the Rapid Transit Railway for a period of 50 years, and at the end of that period to surrender the lease to the city of New York. During the 50 years of the lease the contractor pays to the city a rental made up as follows: (1) An annual sum equal to the annual interest payable by the city upon all the bonds issued by it in order to provide means for construction; (2) a further annual sum which shall be equal to 1% upon the whole amount of the said bonds, except that the annual payment in excess of such interest shall, for each year during the period of five years from the date at which the payment of rental shall begin, be such sum not exceeding 1% as shall be equal to the excess of the profits of the contractor for such year in the operation of the road over 5% upon the capital of the contractor invested in the enterprise, and except, further, that for each year during a second and immediately succeeding period of five years, there shall, in lieu of such 1%, be paid one-half of such 1% and in addition an amount not exceeding one-half of such 1% which shall be equal to the excess of the profits of the contractor for such year in the operation of the road over 5% per annum upon his capital invested.

The lease provides that the contractor shall run trains of two kinds, viz.: local trains and express trains. The local trains are to be run at an average speed, including stops at stations, of not less than 14 miles per hour, the express trains at an average speed of 30 miles per hour. The longest interval between trains stopping at all stations was to be 15 mins. The fare to be charged was not to exceed 5 cts., except that in no more than one special car to such train an extra fare might be charged. No more than one smoking car was to be provided on each train. The contractor was allowed to handle freight and express traffic provided it did not interfere in any way with the use of the road to its fullest capacity to handle all passengers who should desire to be carried upon it. At the conclusion of the lease the city was to have the right to purchase at a reasonable price the whole property of the contractor employed in the operation of the road. Upon suitable application being made by the contractor a renewal of the lease for a period of 25 years was allowed, at an annual rental of not less than the average amount of the annual rental for the last ten years of the original lease.

SUMMARY.—To summarize briefly, the plan under which bids were requested provided for the building of the railway by the contractor according to the specifications of the Rapid Transit Commission and its operation for a period of 50 years. The contractor receives his pay in long-term bonds issued by the city of New York. In addition to constructing the subway, the contractor is to operate it for 50 years, must provide the rolling stock and motive power himself and pay a rental to the city of an amount equal to the interest on the bonds plus 1% for a sinking fund to retire the bonds. At the end of 45 years it is calculated the bonds will have been paid off. When the contract expires at the end of 50 years the city agrees to buy the rolling stock and other equipment from the contractor at a price to be agreed upon by arbitration. By this plan the city in 50 years becomes the owner of a rapid transit subway without any cash outlay and assumes no financial burden except that it stands behind the bonds in case the contractor fails and is unable to pay the interest on them. The contractor is thus able to secure money at a lower rate than if he used his own credit to issue bonds and stock; he is saved the expense of financing the scheme, and, furthermore, he is operating, not under a franchise which can be altered by legislation, but under a definite contract, which cannot be broken by any laws that may be passed.

A CONCRETE DAM has been built across Canada or West Brook, near Providence, R. I., to make good the destruction of two dams in March, 1901, as described in our issue of March 21, 1901. The dam appears to be 353 ft. long, over all, and to be somewhere in the vicinity of 20 ft. high at the maximum section. Mr. Mark W. Scofield, of Providence, R. I., was engineer for the new structure.

CONCRETE AND BRICK RESERVOIR AT CANTON, ILL.*

In 1901, an additional storage of water was provided by building a reservoir of 1,137,000 gallons capacity. The amount of water delivered to the city daily averages 142,000 gallons. The reservoir is rectangular, 160 × 80 ft., with corners of 20 ft. radius. It is 13 ft. deep (7 ft. in excavation) and carries 12 ft. of water to the overflow line. The bottom is of concrete 10 ins. thick, including a ¾-in. coat of Portland cement mortar. The two first footings of the side walls and the coping are also of concrete. The walls are of brick.

The concrete was mixed in the following proportions: 1 part Portland cement, 3½ parts clean sharp sand and 7½ parts medium crushed rock, by measurement. These proportions were determined as follows: The voids in the crushed rock were found to be 40%, and 30% in the sand, giving 12% for cement; dividing this by 12 gave 1 cu. ft. of cement to 3½ cu. ft. of sand, to 8½ cu. ft. of crushed rock. Adding 10% to ensure a good mixture we have 1 to 3½ to 7½. One 95-lb. sack of cement contains 0.9 cu. ft., and is mixed with 3 cu. ft. of sand and 6¾ of rock. We mixed the concrete in batches of 3 sacks of cement to 9 cu. ft. of sand and 20¼ cu. ft. of rock. The sand and rock were measured separately, the sand and cement mixed dry, then shoveled into a pile with the rock, well wetted, shoveled over again and then shoveled into wheelbarrows. The cement coat was mixed with 1 part cement to 2¼ parts sand, and was spread and worked smooth with the trowel.

The concrete work cost $5.38 per cu. yd. in place, as follows:

Medium crushed rock, 0.857 cu. yd., at $2.17.....	$1.86
American Portland cement, 0.586 barrel, at $2.50..	2.14
Sand, 10.1 bushels (100 lbs. per bushel), at 5¾ cts..	0.58
Labor, mixing and placing concrete, 19 cts. per hr..	0.80
Total.....	$5.38

The cement in sacks cost 62½ cts. per sack. The mortar for the brickwork was mixed 1 part of cement to 2¼ parts sand. Each course was laid and then grouted to secure a light wall. The inside and outside of the wall were plastered with a ¼-in. Portland cement coat. No. 1 paving brick was used, costing $6.50 per 1,000, delivered; and the cost of the brick masonry in place was 31 1-5 cts.

The bottom of the reservoir has a fall of 10 ins. to the center, from which a 6-in. pipe leads to the drainage well, which is connected in the same way with the receiving basin at the artesian well. A 10-in. drain leads from the drainage well to the creek, 200 ft. distant. The pipes are fitted with valves so that either the basin or the reservoir can be emptied for cleaning while the other is in use.

The first footing course of the reservoir wall is of concrete, 12 ins. thick and 40 ins. wide, the bottom of the reservoir extending 11 ins. beyond it. The second footing course is also of concrete, 12 × 33 ins. The brick wall is 29½ ins. thick at the base and 13 ins. at the top, where it is covered by a concrete coping 17 ins. wide, 6 ins. thick and marked off in blocks 6 ft. long. There are 20 pilasters or buttresses in the brick wall, 20 ft. c. to c. They are 51 ins. wide, 29½ ins. thick to within 13 ins. of the coping, and then 21½ ins. thick to the top. The cost of the reservoir complete was about $7,900.

*Extract from a paper on "Water Supply for Small Cities," by Mr. G. W. Chandler, of Center, Ill., presented at the annual meeting of the Illinois Society of Engineers and Surveyors at Joliet, Ill.

THE INCOME ACCOUNT OF RAILWAYS IN THE UNITED STATES FOR 1900-01.

The statistician of the Interstate Commerce Commission, Mr. Henry C. Adams, has submitted to that body a preliminary report of the income and expenditures of railways in the United States for the year ending June 30, 1901. This report is based upon the returns from 668 operating roads, representing 192,193 miles of line, or about 98% of the total operated mileage of the country. The summary given in this report of the earnings from operation and operating expenses for the years 1893 to 1901 is presented in the accompanying table.

The report goes on to give other summaries stating operating expenses and earnings by territorial groups, and also earnings and dividends for the two years 1900 and 1901. According to the latter, $121,108,637 was paid out in dividends in 1901, as compared with $108,210,652 expended for the same purpose in 1900. If to this amount is added the sum of dividends paid through the agency of subsidiary lines, and not included in the report, the total dividends for 1901 would exceed $150,000,000.

Item.	Amount.	Proportion to t'l earnings.	Per mile of line. 1901.	1900.	1899.	1898.	1897.	1896.	1895.	1894.	1893.	Increase in 1901.
Passenger service ...	$426,909,210	27.05	$2,221	$2,067	$1,928	$1,813	$1,726	$1,816	$1,764	$1,961	$2,120	$154
Freight service	1,114,740,770	70.64	5,800	5,466	4,895	4,773	4,240	4,344	4,130	4,002	4,996	334
Other earnings from operation	36,501,931	2.31	190	188	181	168	155	157	153	145	163	2
Unclassified	12,294	.....	...	1	1	1	1	3	3	1	1	1
Total gross earn'gs	$1,578,164,205	100.0	$8,211	$7,722	$7,005	$6,755	$6,122	$6,320	$6,050	$6,109	$7,190	$489
Less operating exp...	1,023,156,281	64.84	5,323	4,993	4,570	4,430	4,106	4,248	4,083	4,163	4,876	330
Income, from operatn	$555,007,924	35.16	$2,888	$2,729	$2,435	$2,325	$2,016	$2,072	$1,967	$1,946	$2,314	$159

DEDICATION OF THE NEW LABORATORY OF ENGINEERING AT THE STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

Last week Mr. Andrew Carnegie formally presented to the Board of Trustees of the Stevens Institute of Technology, Hoboken, N. J., a new Laboratory of Engineering, erected at a cost of $65,000. The occasion was an informal one; Mr. Carnegie received the keys of the building from the architects, Messrs. Ackerman & Ross, and in turn presented these keys to Mr. S. Bayard Dod, President of the Board of Trustees, accompanying the transfer with a short speech, setting forth the value to manufacturers of the higher education gained by young men trained at institutions like that founded by Mr. Robert L. Stevens. President Henry Morton, of the Institute, then presented to Mr. Carnegie a piece of the first T-rail ever made; rolled under the personal supervision of Mr. Robert L. Stevens, at the works of Sir John Guest, in Wales, in 1830. It was for use on the old Camden & Amboy Railway.

This rail section was enclosed in a solid silver casket, surmounted by the figures of two men working at a rail-mill: on the sides of this box were representations of the first train run on the Camden & Amboy Railway, and on the ends were medallion portraits of Mr. Stevens and Mr. Carnegie. At the four corners of the box were small figures representing an early iron-worker, an armorer of the Middle Ages, a blacksmith, and a Stevens graduate.

In accepting this gift Mr. Carnegie suggested as his own epitaph—"Here lies a man who knew how to get around him a great many men who were much cleverer than he was himself."

After the ceremonies a dinner was served, with the tables representing a workshop. Punch ran from a miniature blast-furnace into small ladle-cars distributed by a narrow-gage railway, which made the circuit of the table; small flat-cars were loaded with confections in the form of railway spikes; ice cream was shaped like T-rails, and the oysters were served from a Bessemer converter.

The full value to the professional world of this gift of Mr. Carnegie can be better appreciated when the scope and purpose of this new structure are considered. This Laboratory has two functions. Its first is that of an important adjunct to the education of mechanical engineers; with its wide range of types of steam engines, pumps and other mechanical apparatus. It has also a department of engineering physics, where students are instructed in the actual use of all manner of measuring instruments, from huge testing machines to micrometer devices. The other important function of this Laboratory is the investigation and solving of new problems in engineering science; and much work of this nature has already been done in past years, at the Institute, as is shown by its published records.

THE QUEEN VICTORIA NIAGARA PARK COMMISSION presented its report to the Ontario Legislature on Jan. 29. The Canadian Niagara Power Co. agreed originally with this commission to complete by July 1, 1903, the installment of 25,000 HP. and 10,000 E. HP.; but this power company some time ago asked an extension of time and was then much behind in its construction. An amended agreement gave this company until July 1, 1904, to complete; but it had to expend $250,000 before July 1, 1902, and $1,500,000 before July 1, 1903. The power company had to make connections for the development of 50,000 HP., and an outflow of at least 100,000 HP.; and have actually ready for use 20,000 electrical horse-power by July 1, 1904. Since this agreement was made, the Park

Commission reports that the power company has actually expended for work, and have entered into contracts for work in progress and machinery, an amount exceeding $1,750,000. Under the new agreement the power developed will be double that originally proposed. The Park Commission has also made a new agreement with the Ontario Power Co., which proposes to use water from the Welland River, with a power house in the gorge below the Falls.

ANKYLOSTOMIASIS, an old intestinal disease attacking laborers in mines and tunnels, has lately been traced to a specific parasite, by Dr. H. F. Goldman, official physician to the Brennberg coal mines, near Oldenburg, Germany. The disease which also attacks horses and mules engaged in mining work, may be contracted from the air or by contact with the germs, which are really the eggs of the little worms, or ankylostoma. The name signifies "hooked mouth," from the six hooked teeth about the mouth of the parasite, and by which it clings to the interior of the intestines. The female lays an enormous number of eggs, which develop best in a temperature of 65 to 85° F. The disease is due to the heat and moisture of underground workings. Dr. Goldman mentions no specific cure.

FAILURE OF THE LOWER TALLASSEE DAM AT TALLASSEE, ALA.

Of the four Southern dams that failed or were damaged by floods on Dec. 29 we have already given more or less information regarding the Upper Tallassee, at Tallassee, Ala., the Portman Shoals, near Anderson, S. C., and the dam at Columbus, Ga. After various unsuccessful attempts in other directions we have at last secured information regarding the Lower Tallassee Dam from Mr. B. O. Watkins, of Birmingham, Ala., the contractor who built the structure.

Fig. 1 shows a cross-section of the dam, together with a graphical study* of its design, based on 8 ft. of water flowing over the crest. The depth of flood at the time of the failure, according to a statement made by Mr. B. H. Hardaway, was 6 ft. 8 ins. Fig. 2 is a view of the closure of the dam, taken in October, 1901, and Fig. 3 shows a portion of the completed structure, with water flowing over its crest. Finally, in Fig. 4, the break at the west end of the dam may be seen.

The dam was built across the Tallapoosa River by the Tallassee Falls Manufacturing Co., of Tallassee, Ala. It had a total length of about 1,300 ft., of which 235 ft. at one end and 283 ft. at the other was straight, and the portion between was curved up-stream. The maximum cross-section was about 30 ft. high. The corresponding bottom width was about 23 ft. and the top width was 6 ft.

The entire dam was composed of masonry laid in cement mortar. Mr. Watkins states that it was all "carefully hand laid work, no grouting being allowed." This statement is of particular interest, in view of the discussion which has been going on in our columns over the grouting in the Upper Tallassee Dam.

The curved portion of the Lower Tallassee Dam withstood the flood without damage, but practically all the straight lengths at each end went out. The extent of the damage, from the crest downward, cannot be stated, but Fig. 4 shows considerable masonry still standing in that portion of the west end which is included in the view.

The shorter length of straight dam had been completed some 60 days only before the failure, but the other straight section had been finished about 2½ years.

*We are unable to state by whom this graphical study was made.

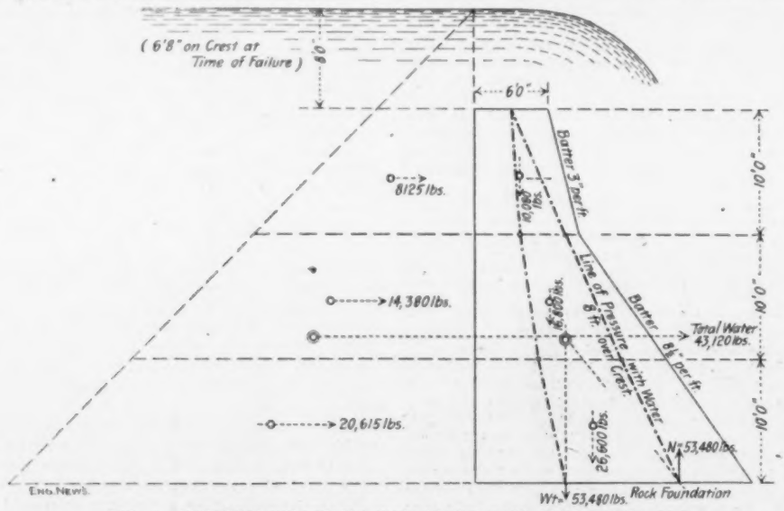

FIG. 1. SECTION OF LOWER TALLASSEE DAM, TALLASSEE, ALA.

REPORT OF THE NEW YORK STATE RAILROAD COMMISSION ON THE PARK AVE. TUNNEL COLLISION.

On February 7, 1902, the Railroad Commissioners of the State of New York issued their report on the collision in the Park Ave. tunnel, on Jan. 8, in which, as reported in our issue of Jan. 16, 1902, 16 persons were killed and a large number of others injured. The report first considers the question of responsibility for the accident, and then, after describing the conditions involved, makes certain recommendations looking toward their betterment.

In regard to the blame for the disaster, the report says (we quote from the New York "Times"):

That the engineman of the Harlem train was inexperienced; that he lacked reasonable presence of mind when he had lost or failed to see his signals, and that he unmistakably violated the well-known rule, which, under the conditions surrounding him, required him to stop his train.

That the New York Central & Hudson River Railroad Co. was grossly negligent of its obligations to the public in putting an engineer of such limited experience and unascertained capacity in charge of a passenger train for operation through this tunnel in what are called the "rush hours."

That the New York Central & Hudson River Railroad Co. has been negligent, derelict, and unprogressive in failing to take measures to increase its terminal facilities at the Grand Central Station and yard by such extensions as would reasonably keep pace with the yearly increasing traffic necessities of the lines entering this station.

That the said railroad company has been negligent in failing to examine more closely into the qualifications of new engineers and lax in discipline in failing to hold engineers to accountability for violation of the running rules of this tunnel.

In discussing the conditions in the tunnel and at the terminal at the Grand Central Station, the report prefaces some of the general aspects of the problem and the relation of the commission to the matter. Attention is called to the fact that the main difficulty is not the tunnel itself, but the dead end station just south of the tunnel. However, since most of the public agitation both previous to and after the accident of Jan. 8 had been directed against the tunnel, the commission deals fully with all suggested methods of improvement, both temporary and permanent:

The best method of dealing with the tunnel itself would be to take off the roof and reopen it, as a cut, to both light and ventilation, using bridges at the intersecting streets. From the public point of view this change is deemed impracticable and intolerable.

The operation of the tunnel as a single-signal block would be as safe, in this respect, as a railway tunnel can be made, but it would be impossible to handle the traffic here—to transact the daily public business within the hours when the people who patronize the road require it to be done.

It is not safe or advisable to light the tunnel in the sense of making a clear illumination in it, though this idea has been advocated with intensity in many quarters as the "solution of the problem." It is not deemed feasible by practical men. It was tried in 1891 under the direction of the Railroad Commission, but the lights were removed soon afterward upon the written remonstrance and request of 88 enginemen employed on the tunnel run. The proposition is opposed to-day by locomotive engineers generally, who are the prime judges of the difficulties to be overcome in running trains through this particular tunnel.

There does not appear to be any feasible way of ventilating this tunnel. The most trustworthy civil engineers who have appeared before this board say they regard ventilation, either by forced draft or by suction, as impracticable.

The present power of this board, under the laws, is not sufficient to enable the board to require a change from steam to any other motive power. But the bill already prepared by this board, and introduced, on its request, in both legislative houses, will confer the authority necessary for that purpose. The act of the legislature (Chapter 702, Laws of 1872,) under which the then open cut from 80th St. to 94th St. was converted into the present tunnel, expressly limited the railroad company to the use of steam power. The original tunnel, it may here be remarked, consisted of a rock bore of two city squares, from 94th St. to 96th St. The whole of the tunnel as it now exists, from 94th St. south to 50th St., is artificial, and was constructed by the railroad company and the city of

FIG. 3. LOWER TALLASSEE DAM AFTER COMPLETION.

New York jointly, under special legislative authority, the city paying one-half of the cost and providing three out of the four members of the governing board.

The tunnel itself is not especially difficult for the operation of the trains, except as it is obstructed by steam and gases from combustion, and by occasional fogs, taken in connection with the immense volume of traffic which passes through it to the immediately adjacent terminal and train yard. The railroad company has year by year during the past ten years felt the absolute necessity of escaping from its cramped environment at that terminal; yet, when it but recently made improvements in the Grand Central Station in the line of comfort and elegance, it unwisely extended the station northerly some 70 ft., thus reducing by that amount the length of the tracks in the train yard proper. This was, in the opinion of this board, a step in the wrong direction.

The size and available shape of the yard is such that nearly all traffic going into or emerging from the tunnel, over its four tracks, must go over but two tracks for several hundred feet, in the yard between 55th St. and 48th St., and these two main line tracks are crossed more or less frequently by practically every outgoing regular train or shop train or engine. This cramped condition as to yard room is the main source of the present troubles in operating the tunnel itself, because it necessitates the passing of nearly all of the regular trains back and forth, empty, between the station yards and the shops and yards at Mott Haven, for cleaning and storage. The testimony is conclusive that this "shuttling" of empty trains and light engines through the tunnel in both directions occasions not less than 40% of the present daily movements of time and distance than formerly. This latter requirement, however, brought a new complication for the locomotive engineers by creating a greater exhaust of steam in the event of their being stalled, and, at times, made it difficult for them to get ahead of their own steam. The board has consequently substituted for that order a requirement that trains shall not pass through the tunnel in less than 5 mins. This will fix the maximum of speed at about 24 miles per hr., and, in the opinion of engineers, will give them safe and sufficient headway.

Signaling experts, who have testified before the District Attorney and this board, unite in declaring this tunnel to be the most perfectly equipped as to its signals in the world; but they at the same time declare that they know of no other tunnel so difficult of operation, both by reason of the large amount of traffic going through it and its unfortunate location so close to the terminal yard. The Baltimore & Ohio Railroad tunnel at Baltimore and the Liverpool tunnel under the River Mersey bear no comparison to it in respect to the traffic.

In 1901 there were 177,450 trains moved through the New York & Harlem tunnel, an average of over 486 per day. And it should be remembered that this movement takes place—through public necessity—almost wholly between 7 o'clock a. m. and 9.30 p. m., or in less than five-eighths of the day of 24 hrs. The time is not many years distant when, even with these contemplated improvements in operation, the increasing traffic of the great city and of this triple railroad terminus will require enlarged and better facilities.

It may be here noted that possible ways of anticipating this need are (a) through the extension of the company's facilities by establishing a new train yard on the Long Island side of the East River, or (b) by increasing and improving the company's existing terminal facilities on the west side of the city, in the vicinity of 30th and 34th Sts. and the North River. By this means perhaps all or a large part of the suburban traffic might be carried to this terminal, and to that extent relieve the Grand Central Station. The surface and elevated roads would quickly extend their connections so as to make that terminus easily accessible, and in any event the probable early advent of the Pennsylvania Railroad to that part of the city would make such a terminal desirable, perhaps necessary.

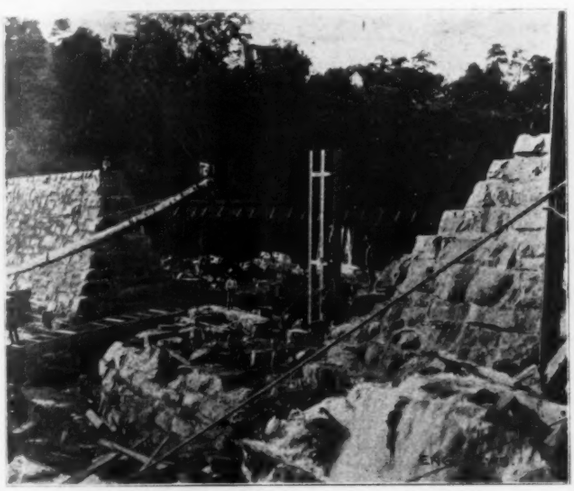

FIG. 2. CLOSURE IN LOWER TALLASSEE DAM.

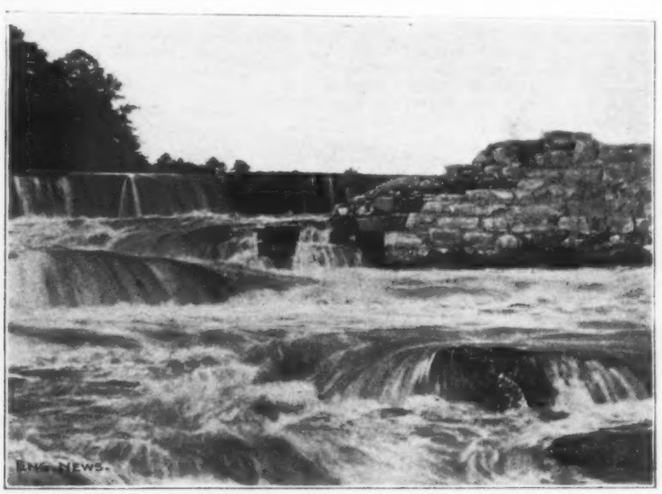

FIG. 4. BREAK IN WEST END OF LOWER TALLASSEE DAM.

in the tunnel, and creates likewise 40% of the obstruction to view arising from steam and gases. The 323 regularly scheduled trains could be managed with comparative ease if the yard room was ample.

The railroad company has felt this need for at least three years past, and it has been the subject of much public discussion, more particularly in connection with the intolerable atmospheric conditions which affect passengers in passing through the tunnel in the summer. The rejoinder of the officials to this criticism has been that the required real estate for the enlargement of the yards could not be obtained, and that as to electricity there was then no feasible system by which the volume of traffic could be handled. Now, however, partly owing to its awakened sense of its own business necessities and partly to the recent rapid advances in electrical engineering, the company has been forced into bringing forward a plan for improvements which will embrace an increase of the yard room and the separation of the suburban traffic from the through traffic by carrying suburban trains underground from the tunnel by a loop system to an independent station, and operating the local trains by the multiple-unit electric plan.

This appears to this board to be the solution of the problem of to-day, but unfortunately it cannot be immediately carried out, nor can it be done in much less than two years. The newly acquired surface area, added to the present yard through recent purchases, will give some relief by affording more room for car storage, and the board urges emphatically upon the company the pressing necessity, as well as duty of the corporation, to put this relief into effect without delay. The board believes that this modicum of betterment should be accomplished within a few months.

In the meantime the board, among other requirements, has directed that no smoke be emitted in the tunnel and that trains be run at what it believes to be safer intervals

The specific recommendations of the commission for present amelioration of the tunnel and terminal traffic conditions are:

A. That the signal or train block in the tunnel, between 55th and 58th Sts., be abolished on all four tracks, and its trackage added to the next northerly block, which extends to 72d St. on the inbound track and to 73d St. on the outbound track. This change will give the new south block, which is now approximately 788 ft. long, a length of 4,419 ft. on the inbound tracks and 4,640 ft. on the outbound tracks. The middle block, extending from 72d St. to 86th St. on the inbound tracks and from 73d St. to 87th St. on the outbound tracks, is about 3,800 ft. long. The northern block, extending from 86th St. to 98th St., is now 3,219 ft. long on the inbound tracks, and from 87th St. to 97th St., on the outbound tracks, is 2,598 ft. long.

B. That this block last referred to be lengthened by removing the signals on the inbound tracks, now at 98th St., to 102d St., and on the outbound tracks from 97th St. to 101st St., and, further, that the location of the crossover tracks, now at 97th and 98th Sts., be changed to corresponding positions between 101st and 102d Sts. This change will make this block 4,286 ft. in length on the inbound tracks and 3,645 ft. on the outbound tracks. The board is of the opinion that these last-mentioned signals and cross-overs are now too close to outbound trains emerging from the north end of the tunnel. The board will watch the operation of the tunnel in three blocks with especial care, and if it results favorably will next give attention to the feasibility of adopting a two-block plan, which, if practicable as to time and the volume of traffic, will doubtless conduce to greater safety in operation. The fact will remain that all railroading is dangerous and that only relative safety can be obtained by the best rules, devices, and discipline.

C. That all distant and home lamp signals on the fireman's side in the center tunnel be placed on standards or spindles at a height of 9 ft. above the top of the rail, so that the lens will be on a level with the cab window, and that in the side tunnels the lamps be raised to a height of 9 ft. above the top of the rail on each side of the tunnel; also that each home signal lamp be duplicated by placing an additional lamp of the same size and power 2 ft. above, or 2 ft. below, the 9-ft. light, as may be found most serviceable. The use of fresh soft coal in locomotive furnaces while passing through the tunnel has already been forbidden by this board, and any firing, or stoking, hereafter done within the tunnel must be done only in emergency, and anthracite coal or coke only shall be used.

D. That temporary changes in the yard tracks, to be made on newly purchased property, be begun forthwith and completed without delay.

E. That the proposed underground suburban traffic loop, the plans for which have been adopted by the Board of Directors of the New York Central & Hudson River Railroad Co., and which have been put in evidence before this board, be carried to completion with all diligence as soon as the necessary legislation is had.

Some other matters, of less importance, are considered at the end of the report:

A large number of letters has been received from inventors and patentees of various safety devices, but few, if any, of them have been tested in practical use, and it is not the function of this board to test untried devices, neither will it undertake the responsibility of recommending them to railroad officers.

Much has been said publicly on the subject of steel-framed passenger coaches as being in common use on railroads, and it has been asserted before the board that special cars for official use are built on steel sills. There are no such cars in general use on any road, nor does the board know of any in private use. Car builders say they would be so heavy as to be impracticable. They further declare that the body frame of the telescoped rear car of the New Haven train was of the same character as the body frame of a Pullman sleeper or drawing room coach; that it was in good condition, nd that the Pullman fittings and finish might be properly placed in it.

In conclusion the board deems it proper to say that it will request the responsible companies to give close attention to details of signal and train equipment and operation, and to the discipline and efficient service of train crews during the period required for making all of the contemplated changes, whether temporary or permanent. These details will be communicated to the companies through special letters and upon personal inspection by the board and its inspectors.

Ashley W. Cole,
Frank M. Baker,
George W. Dunn,
Commissioners.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

One by one those American cities which have so long been suffering from the needless sacrifice of human lives which inevitably accompanies the use of impure water are redeeming themselves by introducing new and wholesome supplies or by erecting the most approved type of purification works. The latest city to redeem itself from the great municipal shame of supplying its people with water which is both offensive to the eye and the prolific cause of typhoid fever and death is Pittsburg, Pa. Elsewhere in this issue may be found a large number of illustrations of the new sedimentation basins, and slow sand filter beds for which bids are to be received on Feb. 24. The text accompanying the illustrations reviews briefly the six years' work at Pittsburg preparatory to letting contracts and supplements the illustrations by descriptive matter, mostly drawn from the specifications.

Two of the many interesting features of the Pittsburg filtration plant deserve special mention. These are the underdrainage, or pure water collection system, and the labor-saving devices for moving the sand to and from the sand washers. The collecting drains are most carefully designed to effect a maximum of work with a minimum of expense for construction, and at the same time to ensure a uniform rate of filtration over the whole of each bed. The lateral drains are relatively few, diminish in size toward their outer extremities, and have, in some cases, carefully proportioned compensation orifices at their junction with the central, water-tight collecting drain. To collect and transport the dirty sand, there will be provided portable sand ejectors, connected by detachable hose and a fixed pipe system with the sand washers, while to replace the clean sand small cars and a complete track system will not only convey the washed sand to each bed, but, by means of portable track, will lay it down on the surface of the bed. As we have said, these are but two of the many special features of the Pittsburg filters. The design of the plant, as a whole, like the experiments which preceded it, is a notable achievement in the water purification field.

THE VENTILATION OF RAILWAY TUNNELS UNDER CITY STREETS.

Is it or is it not practicable to ventilate railway tunnels operated by steam locomotives? An affirmative answer to this question has been repeatedly given in these columns. On the other hand the officers of a great railway company and their engineering advisers have taken a diametrically opposite position. The Chief Engineer of the New York Central & Hudson River R. R., as reported in our issue of Jan. 30, declared that no system of ventilation was practicable for improving the Park Ave. tunnel, and that the only possible means of improvement would be either to remove the roof of the tunnel or adopt electric traction. Being debarred from the first remedy, his company is preparing to spend several million dollars for the second.

This question is of a much larger importance than is generally realized. It is not alone the New York Central railway and New York City that is affected. Every railway company entering a city through a covered subway and every city where such subways are located is interested in this matter; nor does it end even here. No one doubts that in the future many cities and large towns, where railways now run through the streets, will have the present risk and annual sacrifice of lives and limbs removed by the elimination of grade crossings. This means that the railway lines must be either elevated above the streets or depressed below them.

Up to the present time, in considering problems of this sort, engineers have had their choice between building elevated structures and depressing and covering the tracks. Topographical conditions may make the one or the other plan preferable; but not infrequently it happens that either solution may be adopted, and where this choice has been given, many engineers have favored depressing instead of elevating the tracks. Trains in a covered subway or tunnel do not spread the nuisances of noise, smoke and steam on every side as do trains on a viaduct. Again, the subway once built costs only a trifle for maintenance, while an elevated structure of steel constantly requires inspection or painting, is short-lived at best, and is, to a greater or less extent, a possible source of danger. A masonry viaduct is free from these objections, but its great cost makes it seldom feasible.

We need not take space further to discuss the relative advantages of the two forms of construction. The point of importance is that if ventilation is impracticable, the subway as a railway entrance to a city must give place to the viaduct. Further, where existing railways enter a city by means of tunnels, if these tunnels cannot be made safe and sanitary for passengers and adjacent dwellers by ventilation, then eventually the question must be faced of either transforming these tunnels to open cuts or operating them by electric motive power.

Surely, then, the question is of large enough importance to demand the careful attention of the engineering profession, especially as engineers and engineers alone are competent to decide a question demanding expert knowledge and vitally affecting such large interests, both public and private.

"But," we imagine some reader saying, "why not adopt electric motive power anyway? Is not it the 'coming power' for the operation of all railways?" To answer this question in detail would lead us too far afield from our main subject. This much can be said, however, that the displacement of the locomotive by the electric motor on steam railways is not yet "in sight," nor can engineers at present see any prospect of such a change taking place. In the absence of any such general change, to adopt electricity merely for the operation of trains at their entrance to a city means a large outlay with no corresponding return. The New York Central's proposed change is an excellent illustration. To cope with the nuisance of smoke and steam in the Park Ave. tunnel it will detach the locomotives from trains at a point five miles from the present terminus at the Grand Central station and haul them the rest of the way by electric motors. This change will hardly reduce at all the locomotive expenses of the company; any slight saving will be quite offset by the cost of shifting trains from one motive power to the other. Thus the entire fixed charges on the investment in electric motive power and the cost of operating the electric motors will be an expense to the company offset by no material saving.

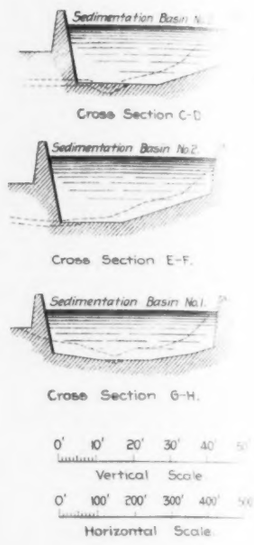
It is, then, important and desirable that railway tunnels should be ventilated. Such ventilation will be the alternative to large outlays for electric motive power, or in new construction for the abandonment of subway or tunnel construction altogether. It is well worth while, then, to see what evidence can be presented for or against the practicability of tunnel ventilation.

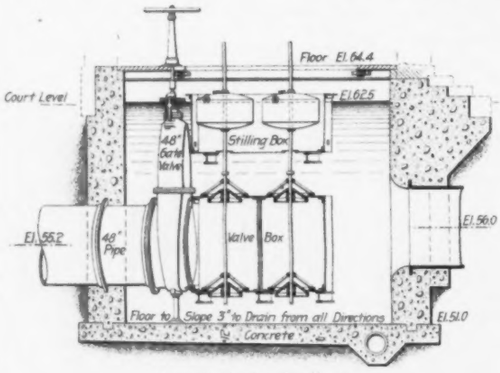
In this article, moreover, we shall (as has already been implied) limit our discussion to such shallow tunnels or covered subways under city streets as are typified by the Park Ave. tunnel in New York city. The problem of ventilating railway tunnels under mountains or under rivers is an entirely distinct one. Great progress has been made in ventilating tunnels of this type in recent years, and several tunnels in Italy and Switzerland and at least one in the United States (the Elkhorn tunnel on the Norfolk & Western Ry.) are now made perfectly safe and comfortable for passage which were before a constant nuisance and source of danger.

With this brief reference, however, we will leave tunnels of this class and turn our attention to tunnels of the covered subway type. These, we are told, it is impracticable to efficiently ventilate, and when we turn to the "state of the art," it must be confessed that there is much to support this view. A large proportion of existing tunnels of this type are not ventilated at all except by more or less infrequent "blowholes" or openings to the street above, through which air is feebly sucked in or expelled from the tunnel by the drafts produced by the passage of trains. On a few of these tunnels in this country and on quite a number in Europe ventilating fans have been installed. These have improved matters more or less according to the degree of intelligence and liberality on which the ventilating plant was planned; but in every case of which we are aware the results attained leave much to be desired. More than this, on two very notable railway tunnel lines electric motive power is to be substituted for steam locomotives, chiefly because of the nuisance caused by the latter. The first of these lines is the London underground railways. Here it cannot be said that fan ventilation ever had an adequate trial, and when the question of ventilation or change of motive power came up a few years ago, it was generally appreciated that electricity was by all odds the system to adopt. Such railway lines as the London Underground are not at all akin to those we are discussing. Not only is the problem of ventilating such lines vastly more difficult, but electric motive power has large advantages which make its adoption worth while apart from the matter of getting rid of the smoke and steam nuisance. We may, then, dismiss these lines as having no bearing on our present discussion.

Probably the most elaborate tunnel ventilation plant ever installed is that which is in use at the tunnel under the Mersey at Liverpool, England. This tunnel is about two miles long and has been operated since its opening in 1886 with steam locomotives, yet now, after these many years of experience, electric motive power is to be adopted for the chief part, if not the whole of the traffic through the tunnel. Surely is this not on its face proof that tunnel ventilation systems are a failure? Here again we must take the opposite ground. A railway tunnel under a river, like the Mersey tunnel, presents peculiar difficulties of ventilation. Did space permit we might point out these in detail; but the interested reader, by referring to the illustration of this tunnel in our issue of Oct. 18, 1894, and the description of its ventilating

FIG. 2. GENERAL PLAN OF SEDIMENTATION BASINS, FILTER BEDS AND CONNECTIONS.





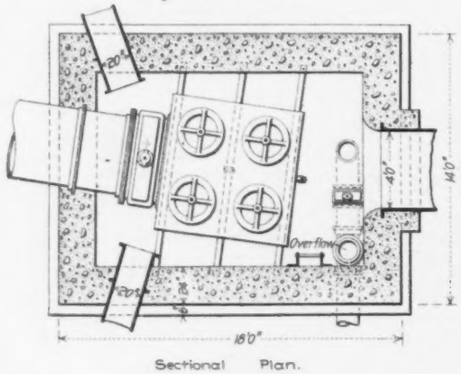


FIG. 5. PRESSURE CONTROLLER CHAMBER.

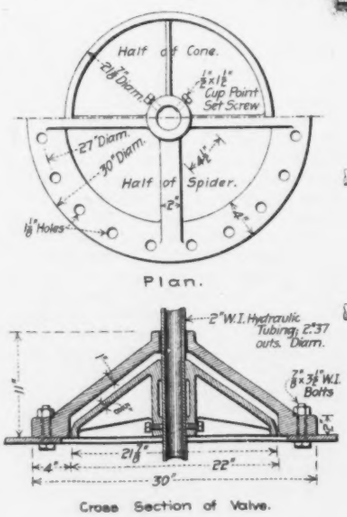


FIG. 6.
PRESSURE CONTROLLER VALVE.

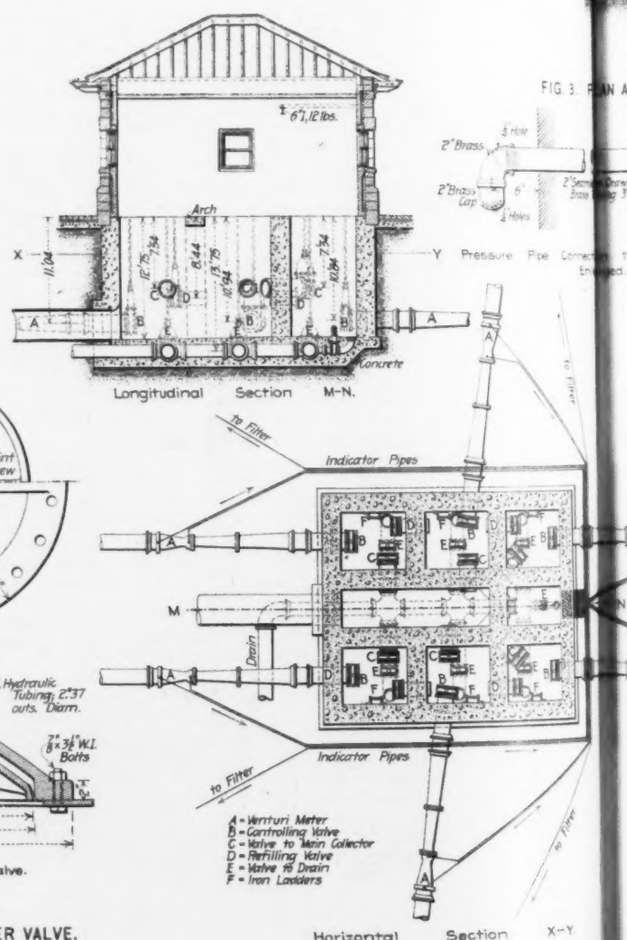


FIG. 7. REGULATOR HOUSE AND CONNECTIONS.

FIG. 3. PLAN AND SE

SEDIMENTATION BASINS AND SLOW SAND FIL

J. Guy McCandless, Director Public Works.

Morris Knowles, Assoc. M. Am. Soc. C. E., President

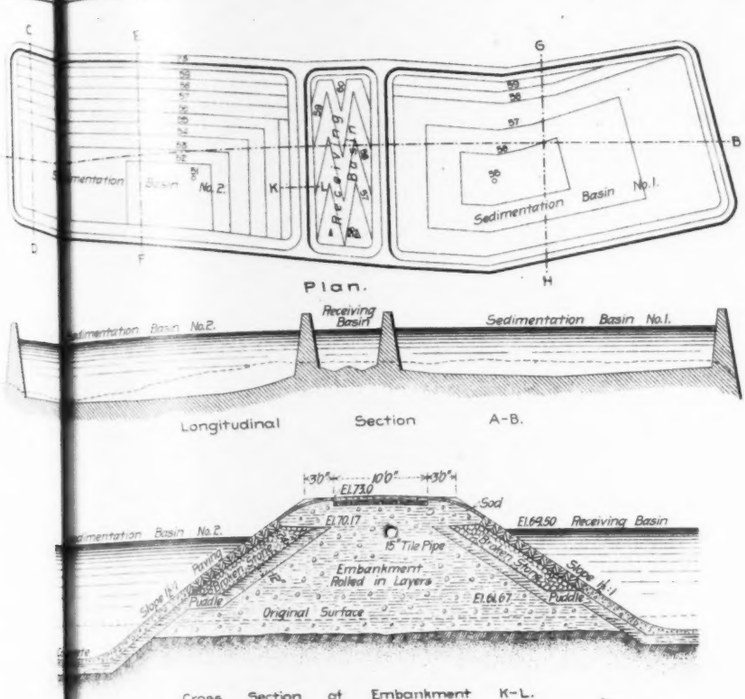


FIG. 3. PLAN AND SECTIONS OF SEDIMENTATION BASINS.

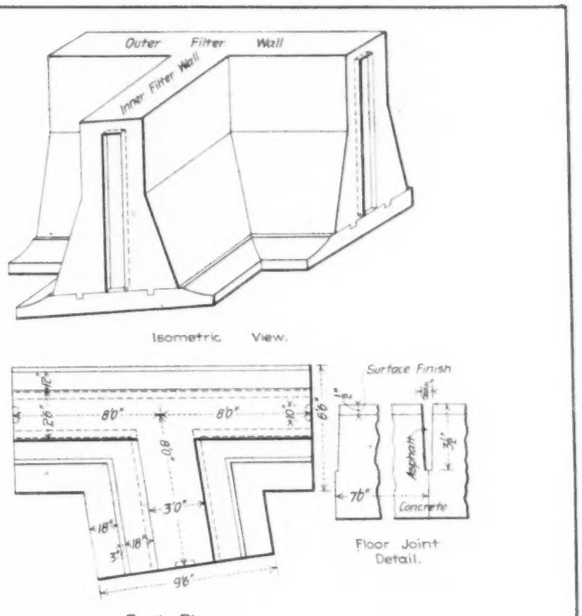


FIG. 4. DETAILS OF CONCRETE FILTER WALLS AND FLOORS.

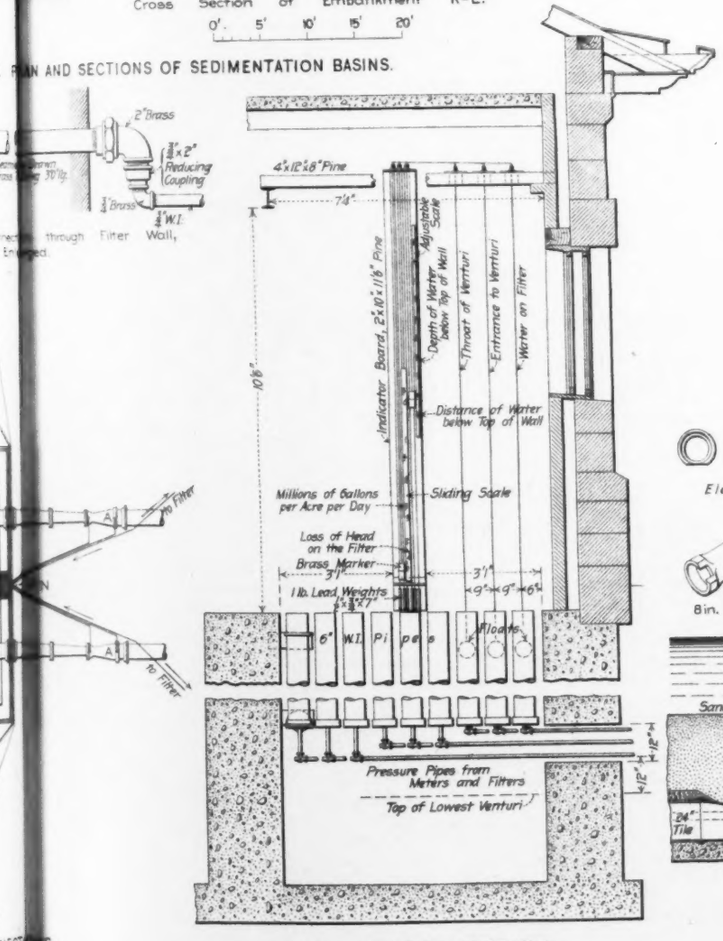


FIG. 8. INDICATOR APPARATUS.

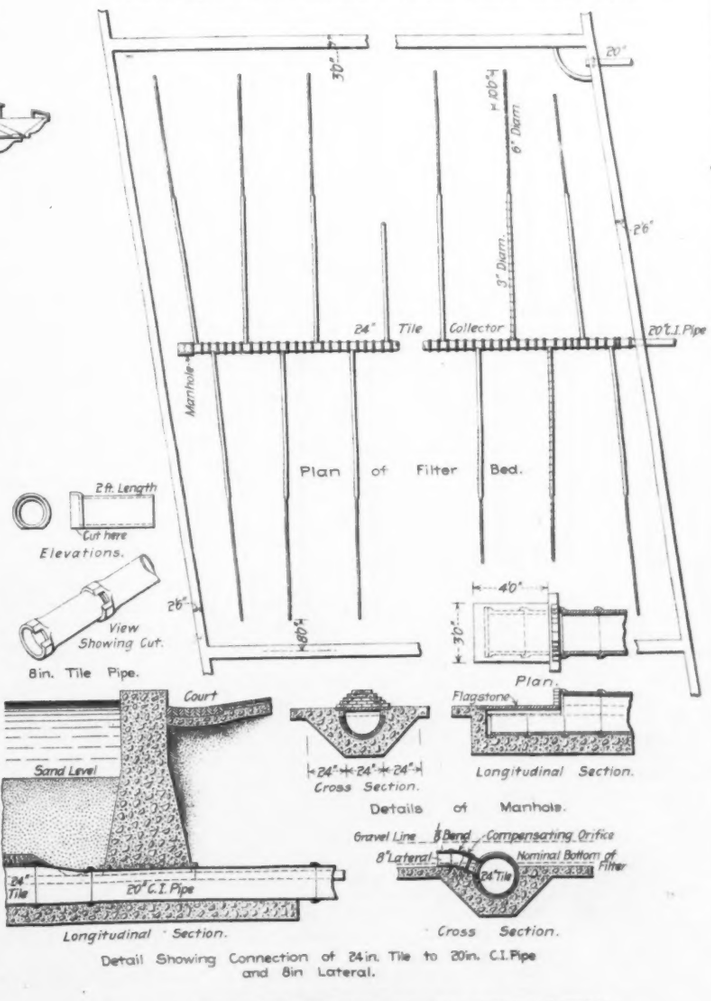
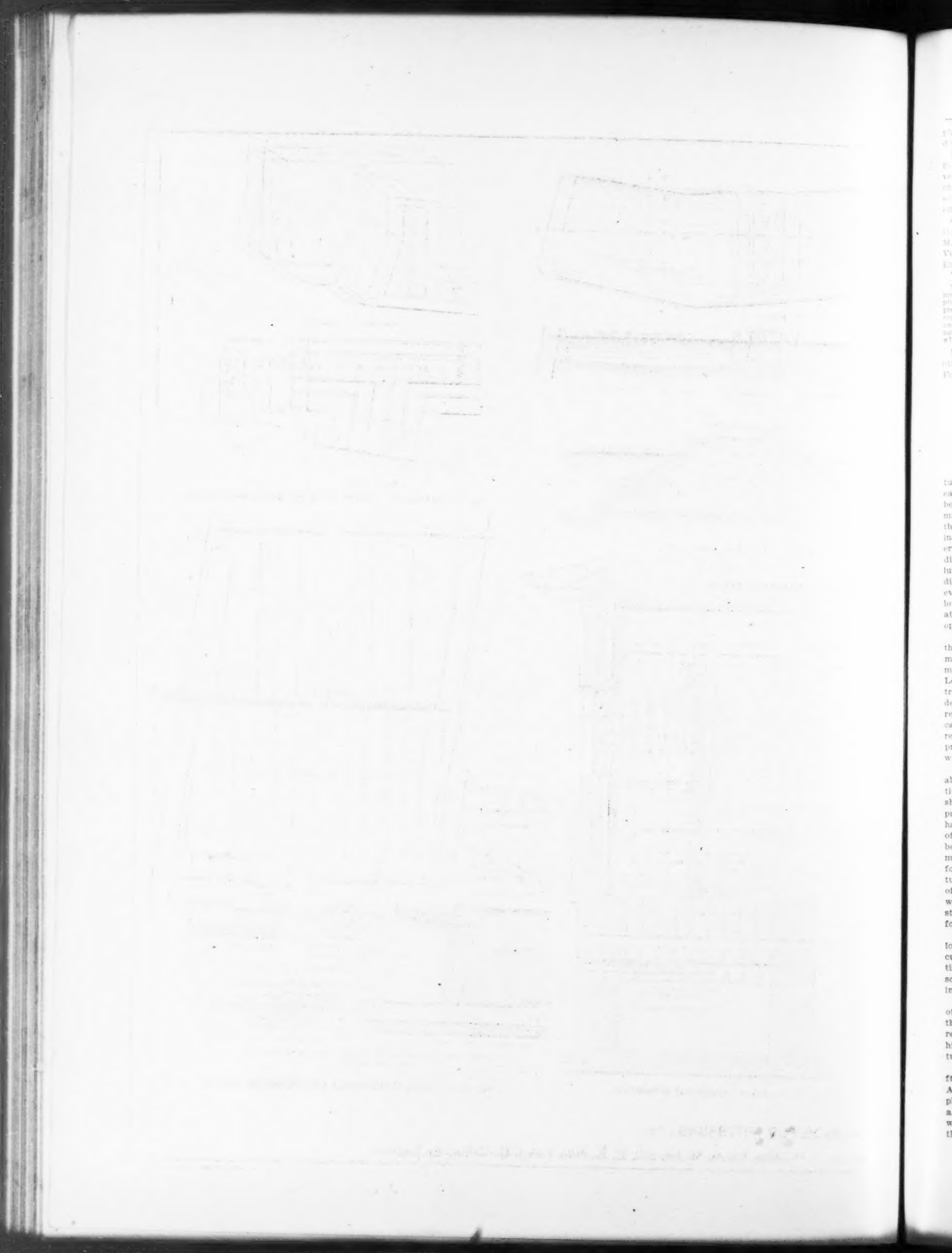


FIG. 9. FILTER UNDERDRAINAGE OR COLLECTING SYSTEM.

) SLOW SAND FILTER BEDS FOR PITTSBURG, PA.

Soc. C. E., Resident Engineer. Allen Hazen, M. Am. Soc. C. E., New York City, Consulting Engineer.

CHAS. HART, LITH., 26 VESEY ST., N. Y.



plant (Eng. News, Aug. 31, 1899), will have little difficulty in determining them for himself.

But turning now from specific examples of efficient tunnel ventilation plants, the opponent of ventilation presents a new argument: If tunnels can be ventilated, then why has not someone, somewhere at sometime, accomplished the work effectively and well?

One of the most effective replies ever made to this question was given by Mr. Francis Fox, M. Inst. C. E., in opening his paper on "Tunnel Ventilation," read before the Institution of Civil Engineers in 1899.

We quote it as follows:

> The principles of ventilation as adapted to coal and metalliferous mines have been fully considered and applied by members of the mining branch of the engineering profession. The author feels strongly that had civil engineers applied to all works under their care the rules and regulations observed by mining engineers, they would not now in many cases be confronted with the evils with which this paper is intended to deal.

It appears to us not at all difficult to perceive other strong reasons than those set forth by Mr. Fox for past neglect of ventilation in the class of tunnels we are now discussing. From the very earliest days of the railway era tunnels have been operated without ventilation and railway managers have been slow to see the need for anything better. Even when it became necessary to install a fan they have been satisfied with a moderate degree of improvement, and have not been disposed to spend more money than was absolutely necessary. All parties concerned have been disposed to accept the smoke of tunnels as an inevitable nuisance of railway travel, and the shallow tunnel in the city street has not received more attention than the tunnels located out on the open road.

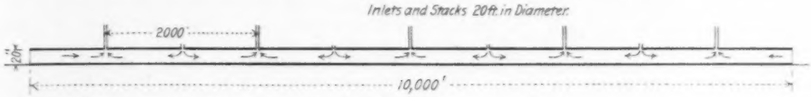


FIG. 1. DIAGRAM ILLUSTRATING PROPOSED BLOCK SYSTEM OF VENTILATION FOR PARK AVE. TUNNEL.

Enough of the past. Its failure to effect more than a partial success in tunnel ventilation is admitted. Let us see what can be done with the means and methods available at the present day. Let us take for our example the central double-track tunnel of the New York Central R. R. under Park Ave., New York city. If the needs and requirements of this tunnel, with its dense traffic, can be successfully met, there will be excellent reason for believing ventilation to be likewise practicable for any similar shallow tunnel wherever it may be located.

The total length of the Park Ave. tunnel is about 10,000 ft. It is divided into four block sections, and while the most southern block is shorter than the others, it will suffice for our present purposes to assume the blocks to be each half a mile long. With trains running at a speed of 30 miles per hour, which has until recently been common, this gives one minute as the minimum interval between a train and the next train following. It is desired now to so ventilate this tunnel that the engineer will have a clear view of each block signal as he reaches it, and this will be effected, it is plain, if all the smoke and steam left by one train is removed before the next following train comes along.

The smoke and steam discharged by his own locomotive need not cause an engineer any difficulty, for the train can run faster than any ventilation current. If it does not, it will be moving so slowly that the engineer will find no difficulty in seeing the signals anyway.

Now, to effect the prompt and entire removal of the smoke and steam left by a train before the next train comes along, we must cause a current of fresh air to flow through the tunnel behind the train with sufficient velocity to clear the tunnel during the interval between trains.

Suppose, now, we divide the tunnel, about 10,000 ft. long, into five blocks, each 2,000 ft. in length. At the center of each of these blocks we will place an outlet to an exhaust fan delivering into a stack, and midway between these outlets we will locate inlets for fresh air. Fig. 1 represents the general outline of such a ventilation system. Now, if we proportion our exhaust fans to produce a current of fresh air from each inlet along the tunnel at a speed of 1,000 ft. per minute, it is evident that the whole tunnel will be cleared one minute after the passage of each train, and the clearing will not be mere dilution of the steam and gases, but an entire replacing of the air in the tunnel.

Now, is it practicable to create such a current in the tunnel? Let us see. A speed of 1,000 ft. per minute is very moderate for moving air, amounting to only 11⅓ miles per hour, no more than the velocity of a gentle breeze in the open air. The cross-section of the tunnel is about 375 sq. ft. (It will be understood that we are referring all the time to the central double-track tunnel alone, electric motive power having been definitely adopted for the two side tunnels.) Suppose we select tentatively 20 ft. square inside as the dimensions for the upcast shafts or stacks into which each fan will discharge. That will give the stack a cross-section of 400 sq. ft., and to give the currents in the tunnel moving each way toward the fan a velocity of 1,000 ft. per minute the velocity in the shaft must be 1,875 ft. per minute, about 20 miles per hour. How much work must be done per minute on the air discharged from the top of the stack at the above speed? This we find by the familiar rule of the weight multiplied by the height due to velocity, or

$$\text{Work} = \frac{W v^2}{2g}.$$

The quantity of air to be moved per minute by each fan is readily found to be 750,000 cu. ft., and dividing by 13, we have the pounds per minute moved. We also find the velocity in feet per second, and performing the computation we find the total foot-pounds in the current of air issuing per minute from the stack to be 872,000. Dividing this by 33,000, we have the actual energy of the issuing air as 26.4 HP.

But besides moving the air in the stack, we must provide power also for the movement of the air in the tunnel. If it were practicable to connect the tunnel outlet to the fan casing and stack by a gently curved passage, the inertia of the air moving in the tunnel would help somewhat the movement of the air in the stack and subtract a little from the power required. It will be safer, however, to allow nothing for this, and so we have the computation; Energy required per minute for movement of air in the tunnel $= \frac{750{,}000 \times (16\frac{2}{3})^2}{2g} = 250{,}000$ ft.-lbs. per minute.

Reducing this to horse-power, as before, we have 7.6 HP. as the actual power required to move the air in each 2,000-ft. section of the tunnel toward the stack opening at the rate of 1,000 ft. per minute.

Besides the amounts of energy already determined, the air current will also absorb power at its entrance to the inlet openings, in the passage from the tunnel to the fan and from the fan to the stack and by friction against the sides of the tunnel and stack. These quantities are better allowed for as a percentage of the power already found than by any attempt at theoretical computation. It can be seen, however, that with the large section of the current and the low velocities, friction should be very small. To be on the safe side, we will assume the sum of all these resistances as equal to the inertia of the air in the tunnel and stack already found, or $26.4 + 7.6 = 34$; $34 \times 2 = 68$.

Taking this, now, as the work to be actually imparted to the moving column of air, what power must we apply to the fan? Many tests of the mechanical efficiency of large mine ventilating fans have been made, with results varying all the way from 25% to 60%, or more. While the low velocity of the air currents would conduce to economy, to be on the safe side again, we will assume the efficiency of the fan to be as low as 25%, making the horse-power of the motor required to drive it:

$$68 \div 0.25 = 272 \text{ HP.}$$

It will be apparent that in the above computation our aim has been rather to find the maximum power required rather than to make any exact estimate, our object, of course, being to test the practicability of the system. It is quite probable that a much smaller power would create ventilation currents with the velocities above specified. Even if this is not the case, however, the operation of a plant of the power stated would be no very serious matter. It is to be remembered that no such train movement as one train per minute on each track is ever likely to continue for but a small part of the 24 hours. Thus the fans would be run at their maximum power only in the rush hours, morning and evening. Inasmuch as the power required to move air varies as the square of the velocity, the power consumption at other times of the day would be very light. An excellent arrangement would be to connect, say, a 75-HP. motor to one end of the fan shaft and a 200-HP. motor to the other. The small motor alone, for example, might run the fan for perhaps 12 to 14 hours, the large motor alone for perhaps 4 hours and both together for the remainder of the 24. This duplication of motors will give ample time for daily inspection and cleaning, and will guard to a large extent against interruptions of the service by breakdowns.

Some engineers may criticise the above estimate of power required because it is small in proportion to the volume of air moved. This is because in existing mine and tunnel ventilation plants much higher speeds and pressures are used than those we have proposed. Too many engineers fail to realize that high speeds and pressures for moving air, while they effect a saving in the first cost of the plant, add enormously to the consumption of power. In many cases these high velocities and pressures are necessary. In tunnel ventilation they are not necessary at all, at least in such a case as that under consideration.

Perhaps the size of the stacks proposed (20 ft. square) may be objected to, and the objection would have weight if it were necessary to place them in the middle of the street. We see no need for such a location, however. A lateral subway may be led from the bottom of the tunnel to an underground fan station located on private property at the side of the street. The height of the stack need be little more than that of the adjacent buildings. The discharge from its top will be so greatly diluted as to be almost absolutely unobjectionable. It may be of interest to compute this dilution. Suppose trains to run at intervals of one minute, and each train to burn 40 lbs. of coal in passing through the section 2,000 ft. long ventilated by one fan. Allowing 30 lbs. of gases to be discharged per lb. of coal burned, and taking their specific gravity the same as air, we have 15,000 cu. ft. as the volume of gases discharged per minute in each 2,000-ft. section. As 750,000 cu. ft. of air are discharged from the tunnel in the same time, the dilution will be about 50 to 1. Of course, no computation of the volume occupied by smoke and vapor is possible; but it can at least be said that the nuisance to the residents from these would be wholly insignificant compared with the present discharge at the street level from the openings in the tunnel roof.

There are two questions regarding the system here outlined which have doubtless suggested themselves to the critical reader. The first is: How would such a system meet the case of the obstruction of the view of signals produced by the discharge from two locomotives passing each other in opposite directions? It must be frankly admitted that practical experience could alone be relied on to determine whether such obstruction would be great enough to constitute an element of danger. If on completion of the ventilation system as above outlined, difficulties of this sort appeared, it would be a simple matter to erect a thin partition wall between the tracks, dividing the tunnel into two single-track tunnels. Such a wall would not need to be of masonry, since its

only purpose would be, like a brattice partition in a mine, to confine the air currents.

Next comes a critic with the inquiry whether the ventilation currents would not be interfered with by the movements of trains, especially if the partition above referred to were erected, making two single-track tunnels. Undoubtedly there would be interference to a certain extent; but it will be apparent on a little study that the train movement helps the ventilation current as much as it hinders it.

Referring to Fig. 2 (a), it will be seen that a train running from A to B will aid the air current as much as it will hinder the opposing current in running through the next section from B to C. This will clear the section A B more quickly than is necessary, and will retard the clearing of B C so that it may not be completely cleared before the following train arrives. Now, to overcome this difficulty we need only locate our inlet openings at unequal distances on each side of the stack. The longest section of tunnel is placed, of course, on the side where the train movement helps the ventilation current; the shorter, on the side where the ventilation current is hindered; and the arrangement is illustrated in Fig. 2 (b).

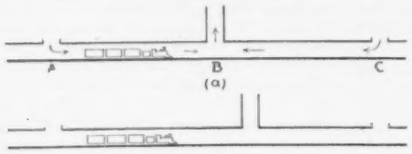


Fig. 2. Ventilating Section of Tunnel, Showing Arrangement to Cause Currents Set Up by Train to Aid Ventilation.

And now let us inquire what other difficulties with ventilation an active imagination can conjure up. It has been stated that ventilation is impracticable because in case the ventilation plant should break down passengers in the tunnel would be in danger of asphyxiation. We have shown above how liability of the breakdown of the ventilating plant at any stack could be reduced to a minimum. Let us suppose, however, that precautions fail and one of the fans is temporarily put out of service; it would then be entirely practicable by manipulating shutters in the air inlet openings to throw the work of this fan upon those on either side for a time. Again, suppose that by some calamity the whole ventilating system has to be shut down. The inlet openings, 2,000 ft. apart, and the natural draft in the stacks would still give some relief. As a matter of fact, the conditions would doubtless be little worse than they have been for years in parts of the side tunnels on Park Ave., or than they are to-day in dozens of railway tunnels here and abroad.

It will be apparent, of course, to the reader that in the ventilating system above outlined we have aimed at a standard of excellence never yet attained in any tunnel ventilation plant anywhere. We doubt ourselves whether so high a standard is by any means necessary for the Park Ave. tunnel even; but we have tried to test the possibilities and approximate cost of making this tunnel as safe and comfortable as it would be if electric motive power were adopted—a remedy which the public and part at least of the engineering profession as well appears to have fixed upon as the only possible solution of the tunnel problem.

We need hardly say that the main reason why a high standard is required for this tunnel is the location of block signals inside it, a condition absolutely necessary to handle the volume of traffic. There is hardly another case anywhere, in this country at least, where a tunnel is not operated as a single block, and under these conditions no such exceptionally high standard for ventilation is likely to be called for elsewhere.

Finally, we may properly note that in the system above worked out our object has been solely to test the practicability of tunnel ventilation according to the standards laid down at the outset, and not at all to present a detailed scheme for adoption. It is altogether probable that better proportions and many improvements could be made in the system as suggested.

We would lay emphatic stress, however, on the principle we have followed—the maintenance of low velocities and the avoidance of all contracted passages. A look at existing tunnel ventilation plants is only too convincing that their designers have almost invariably had no real understanding of the importance of this principle. It has been attempted to ventilate tunnels with a cross-section of 300 to 400 sq. ft. through parallel drifts with a cross-section only an eighth or tenth as great. Small high-speed blowers have been installed to move the air instead of large, low-speed mine ventilating fans. If engineers will only keep in mind that air, like water, has weight, and that the power required to move it increases with the square of the velocity imparted to it, better design and better results in tunnel ventilation are certain to be attained.

LETTERS TO THE EDITOR.

Concerning a $40 City Engineer.

Sir: I note in your issue of Jan. 23 that the city of Greenville, S. C., advertises for a city engineer at a salary of $40 a month, with the privilege of taking "some" outside work. I am not an applicant for the place, but am interested to know whether this is a usual salary to offer for such a position in a city of this size (about 11,000 in 1897), and what ratio the duties and pay of his official position bear—generally speaking—to the returns from the "some" outside work. Is it expected that the supposed prestige attaching itself to official position will induce an active and paying private practice, or that young engineers will seek such positions for the experience, or what is the explanation of this offer of day laborers' wages for a position of the importance and responsibility of city engineer? This is not a criticism of Greenville, but a question of engineering compensation which is of far wider interest to our fraternity. S.

New York, Feb. 1, 1902.

Is the Chagres River an Obstacle to the Construction of a Canal at Panama?

Sir: I would like to inquire as to the report of the Isthmian Canal Commission concerning the feasibility of constructing the artificial lake necessary to supply sufficient water at the summit level to operate the Panama Canal. This water, I believe, is to be supplied by the Chagres River, which is claimed by some authorities to be an erratic and untrustworthy stream.

Is not this a disadvantage of the Panama route when compared with the natural and ample Lake Nicaragua?

Very truly yours, D. S. Harrison, Res. Engr.

Arapaho, Okla. Ter., Jan. 31, 1902.

(Under the old De Lesseps plan of a sea level canal at Panama, the Chagres was a formidable obstacle. Under the present plan of a canal with locks, the Chagres discharge will be received into Lake Bohio, with a surface of 38.5 sq. miles, and spillways have been provided sufficient to safely maintain the level of this lake and provide against the greatest flow that can come from the Chagres.—Ed.)

The Inventor of the T-Rail.

Sir: I notice in Tratman's "Railway Track and Track Work," p. 58, the following statement: "The T-rail or flange rail, which is now in common use all over the world, was invented in this country in 1830 by Col. Robert L. Stevens, Chief Engineer of the Camden & Amboy Ry., and the first order was placed in England by him for this road. In Europe this rail is generally called the Vignoles rail, having been re-invented in England in 1836 by Mr. Charles B. Vignoles."

This is evidently an error, as will appear from the following extracts from Millington's "Civil Engineering," p. 678:

In October, 1820, Mr. John Birkinshaw, of the Bedlington Iron Works, Durham, gave the last stage of improvement to railways by obtaining a patent for wrought-iron rails, and for improving their form and mode of application. Before this time common bars of wide and thin iron had been used in a few instances with their edges placed upwards, but they did not answer. Mr. Birkinshaw's improvement consisted in passing bars of iron of proper size and form, when red hot, through rollers like those shown in Fig. 127, Pl. IV., but with indentations or grooves made in them corresponding to the shape of the intended rails. In this way, wrought bars with swelled and rounded tops similar in section to the cast bars before used, and with a flanch at the bottom to promote stiffness, can be produced in lengths of 12, 15 or 18 ft. These long bars are fixed in chairs at their ends where two bars unite, and likewise at about every 3 ft. of their intermediate length, and if these chairs are supported by blocks of stone of sufficient magnitude, well bedded and fixed in the ground, this construction offers as permanent and good a railroad as can be desired.

"Elements of Civil Engineering, by John Millington, Civil Engineer, formerly Professor of Mechanics in the Royal Institution of Great Britain, and of Civil Engineering and the Applications of Science to the Arts and Manufactures in the London University; and now Professor of Chemistry, Natural Philosophy and Civil Engineering in William and Mary College, Va.," was published at Philadelphia and Richmond, Va., 1839.

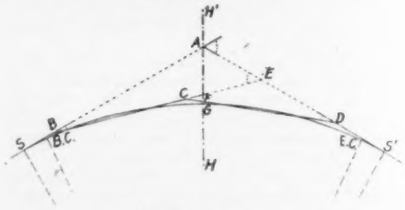
Yours very truly, W. M. Dawley, C. E.

B. & O. Ry., Zanesville, O., Jan. 16, 1902.

(The statement in "Railway Track and Track Work," to which our correspondent takes exception, is entirely correct. Birkinshaw's rail had no flange to the web to correspond to that of the Stevens rail. The thickness of the web was simply increased at the bottom for the purpose of stiffening the rail. The fundamental and essential difference between the Birkinshaw and Stevens rails is in the flange. The former rail was not self-supporting, but had to be carried by cast-iron chairs, like the older cast-iron rails of very similar section, or the present style of English bull-head rails. Col. Stevens eliminated all this complication of separate supports (with their rail attachments) by designing the T-rail with flat-bottomed flange, which section is absolutely self-supporting. Birkinshaw devised a modification of the type of rail then in use, and also introduced the important feature of rolling the rail instead of casting it. Stevens, however, struck out in an entirely new line and invented a form of rail which is to-day in general use in all parts of the world.—Ed.)

Relining Railway Curves.

Sir: The article on this subject in your issue of Dec. 26, 1901, contains many interesting points, which, if carried out, would be appreciated by both trackmen and engineers. Having used an efficient and rapid method for relining curves during the past summer, a brief account may be of interest to those who have charge of such work. There can be no claim to originality, as this method has doubtless been used by other engineers, though suggestions for such work are seldom given in our field books and periodicals.



On this road the "Searles" spiral is used on all but very easy curves. The terms S and S¹ denote the spiral points, while B C and E C are retained to designate the ends of the simple curve between the spirals. By the ordinary method the simple curve is located with the instrument at the B C and taking back sight at S. To avoid the probable error in alinement due to such a short back sight, locate the points B C, E C, and the center G. With the instrument at G and vernier at zero, sighting to B C, the deflection to the E C can be readily checked, and the entire curve, if short, can be run in at this one set-up. However, this method of using the center point G most commends itself in cases of very long, light curves with short spirals, and with B C and E C not visible from G. At the time that G is located from F, set also a point H or H¹ in this same line and distant several hundred feet therefrom. Move the instrument to G, set the vernier at 90°, minus the deflection angle to G, and sight on H. When the vernier is then set to zero the sight will be to the B C. Hence the curve can be run either way from G, using the ordinary deflection angles figured from the B C. If H or H¹ cannot be easily set, the point D or an offset therefrom, equal and parallel to F G, can often be conveniently used.

My usual back sight is a tooth-pick or small stick, behind which is placed a piece of coal, readily found along most of our tracks. Small tins, punched "S., B. C. 2¼°," etc., are nailed at the ends of ties opposite the respective points in the curve. Very truly,

L. E. Ashbaugh.

C. M. & St. P. Ry., Minneapolis, Minn., Jan. 4, 1902.

Relative Merits of Swing and Bascule Bridges and the Saginaw Bridge Letting.

Sir: In your issue of Jan. 30, 1902, appears a letter under the heading "The Relative Merits of the Swing and Bascule Types of Drawbridge for Wide Channels." This letter refers to a Scherzer rolling-lift draw-span which the city engineer of Saginaw, Mich., it is stated, included in a design for a new bridge at Genesee Ave., in that city.

good judgment of the city engineer in doing this is admitted and statements are made, damaging to the Scherzer Rolling Life Bridge Co. Were they made with the intent to influence the next letting?

It is stated that the working parts of a rolling-lift bridge on Genesee Ave., Saginaw, Mich., will be annually from 5 to 7 ft. under water, and for this reason a swing bridge should be built in that place. The writer does not seem to know that the Scherzer rolling-lift bridge can be and is frequently designed and constructed with all movable parts, except the floor, above the roadway; as, for instance, the bridge over Newtown Creek, New York city, the six-track bridge at Boston, Mass., the two bridges of the C., C., C. & St. L. Ry. at Cleveland, O., the C. T. T. R. R. bridge at Chicago, and others. With a swing bridge it is entirely impossible to place the turntable above the roadway floor. A rolling-lift bridge can be constructed with the roadway grade only 2 or 3 ft. above high water, which is about the depth of the floor; for a swing bridge the depth of the turntable must be added and this will bring the grade of the roadway to 7 or 8 ft. above high-water as a minimum for a small highway bridge.

The writer asks: "Is it not better to build a swing bridge with two openings instead of a bascule with one opening?" We ask: Why should two openings be provided when only one opening is necessary? Why should the middle or best part of the channel be obstructed by a center pier and a long swing protection when a clear, unobstructed opening can be obtained by using a bascule bridge? Why should a swing bridge which requires at least a minute for opening or closing be built when a rolling-lift bridge can do the work in less than one-half of that time? Why should the public on the highway and the vessels in the river be delayed by a swing bridge when the rolling-lift bridge is more economical in first cost, operation and maintenance?

The writer states: "Some good bridge engineers object to the Scherzer lift on account of the combined rolling and horizontal movement tending to wrench and tear the abutments to pieces." This alleged objection to the rolling-lift bridge was invented—as far as we have been able to trace it—by rivals in business. As a matter of fact, no pier or abutment of any Scherzer rolling-lift bridge has ever shown any weakness. Our bridges are all in successful operation, among them being the largest and strongest railroad bridges in the world, so that we believe piers can be designed and constructed to safely carry the comparatively small bridge at Saginaw, Mich.

A modern movable bridge intended to permit the rapid passage of vessels should have the following essential qualities:

1. Safety. 2. Adaptability. 3. Reliability. 4. Artistic outlines. 5. Economy.

The swing bridge has long been recognized by good engineers as deficient in all of these essential qualities. Good bridge engineers now recognize the fact that the rolling-lift bridge has many advantages over the swing bridge, not only for narrow channels, but also for wide navigable channels, where there is ample width for pivot piers and a swing span. Some of these advantages are as follows, grouped under the above five headings:

1. SAFETY.—The rolling-lift bridge in itself when open, forms a perfect guard, gate and signal, and effectually blocks the roadway, thus absolutely preventing the many disastrous accidents so common to swing bridges. The City of Saginaw and many other cities have lost lives because of open swing bridges and this inherent danger of the swing bridge is ever increasing on account of increased traffic and the increased speed of traffic. The long swing protection required for a swing bridge is always an obstruction and danger to navigation. It is especially obstructive and dangerous in curved channels and on tide water or rivers with a strong or changing current. With the rolling-lift bridge there is no center pier or protection in the path of navigation, and the clear, unobstructed channel may be any width required.

2. ADAPTABILITY.—The roadway of a rolling-lift bridge can be placed closer to the water than is possible with the swing bridge, because all the movable parts of the former except the floor can be and are frequently placed entirely above the roadway, while the turntable of a swing bridge must necessarily be below the roadway. The rolling-lift bridge can be divided or constructed in any number of parallel bridges, which may be operated either jointly or separately as desired; this, as will be evident, is entirely impossible with the swing bridge. If it is desired to widen a swing bridge, the existing swing bridge with its supporting pier and pier protection and abutments must be discarded and removed. Also, the adjacent fixed spans must be removed and a larger and more obstructive center pier and protection pier must be constructed. New abutments and shorter adjacent fixed spans must be built. This great waste is entirely unnecessary with a rolling-lift bridge: if it is desired to widen such a bridge for increased traffic or future demands of traffic, any number of new bridges can be added parallel to the existing bridge without in any manner interfering with the latter structure, with the traffic across the bridge, or with the traffic in the channel.

As the swing bridge moves horizontally, it moves over adjacent land or water space, and may at some time interfere with adjacent property rights or adjacent parallel bridges. In contrast to this, the rolling-lift bridge moves vertically, entirely within the lines of the roadway and will never interfere with the adjacent dock space, adjacent parallel bridges or any land or water rights, all of which items may, during the life of a bridge, become of great importance, even in the widest rivers. The wider the roadway of a swing bridge, the more obstructive and dangerous the swing bridge becomes to nagivation. This is not the case with the rolling-lift bridge, as it can be made any width desired without encroaching upon the navigable channel. A wide bridge of this type is as unobstructive as a narrow one, as demonstrated by four-track, six-track and eight-track Scherzer rolling-lift bridges in existence.

The swing bridge has always been a curious anomaly among modern engineering structures. The swing bridge usually spans two inadequate channels where only one adequate channel is required. With the rolling-lift bridge it is no longer necessary to span two channels where only one adequate navigable channel is required. It may be urged that it is a great advantage to separate a navigable channel for vessels into two parts by a strong center pier and protection as provided by the swing bridge. If this were true, it would then be desirable to separate navigable rivers and channels by strong piers or partition walls throughout their entire length. With the rolling-lift bridge the navigable waterway can be crossed by the shortest possible movable span and provide an ample unobstructed clear channel for the passage of vessels. This shortens the length of movable bridge required.

The rolling-lift bridge may be erected in the upright position. Its erection is rapid and economical and need never obstruct, divert or delay either railroad, highway or vessel traffic. A dredged navigable channel need never be widened to accommodate rolling-lift bridges.

3. RELIABILITY.—The swing bridge is supported by a large number of rollers, frequently wearing out the tracks, breaking and constantly requiring attention, repairs and replacement, thus causing delays. On the other hand, the large rolling segment of the Scherzer rolling-lift bridge is a part of the movable bridge truss. It moves virtually without friction upon a straight, smooth and level track and a century of maximum use will not wear out either the segment or the track. The rolling segment is the most perfect and most simple known mechanical device to reduce friction in the movement of large masses. The swing bridge requires end lifts and rail lifts. These are not required with the rolling-lift bridge. The rolling-lift bridge is a very rigid structure, whereas the swing bridge must necessarily be flexible and is statically indefinite.

Railroad, highway and vessel traffic are all delayed because vessels are only able to move slowly and with difficulty through the side openings of a swing bridge because of the long obstructive pier protection. Vessels can move rapidly, safely and easily through the openings of a rolling-lift bridge because it provides an adequate unobstructed opening in the center of the navigable channel without any long pier protection obstruction. As a consequence of the rapid movement of vessels through the bridge, highway and railroad traffic across the bridge are greatly facilitated. Time is also saved because a rolling-lift bridge is opened and closed much more rapidly than any swing bridge. It is usually opened or closed within half the time required for a swing bridge of equal capacity. Time is also saved because tugs and small craft require only a partial opening of a rolling-lift bridge. This is especally important when the bridge crosses the channel at a slight elevation above water, as a large proportion of the movements required of a low-level bridge are for permitting the passage of tugs and small craft. The swing bridge cannot move away from a vessel as rapidly a a rolling-lift bridge. It is consequently in danger of being pushed off from the center pier and such accidents have happened. The rolling-lift bridge not only moves away from a vessel more rapidly, but also moves vertically and away from the navigable channel. When a swing bridge is disabled, land or water traffic, or both, are blocked. The rolling-lift bridge can consist of two or more parallel bridges, side by side, some of which will always be available and prevent blocking of either railroad, highway or water traffic.

The center pier and protection pier of a swing bridge causes the formation of sediment in navigable channels. They occupy a considerable area in such channels and require the maintenance and dredging of a larger area than is required when rolling-lift bridges are used.

4. ARTISTIC OUTLINES.—It is impossible to build a swing bridge in the form of an arch and, in fact, the outlines of a swing bridge have never been considered artistic. The possibilities of artistic outlines with the rolling-lift bridge, however, are virtually unlimited. For instance, where artistic outlines are desired in a bridge across a wide river and the fixed connecting spans are arched, the draw-span may also be arched, harmonizing with these spans. The rolling-lift bridge can have the outlines and even the ornamentation of the Alexander III. bridge at Paris and in addition thereto be made movable to accommodate navigation. It is evident that this is impossible with the swing bridge.

5. ECONOMY.—The first cost of construction of a rolling-lift bridge is more economical than the first cost of construction of a swing bridge of equal capacity. The cost of operation and maintenance of a rolling-lift bridge is less than the cost of operation and maintenance of a swing bridge. The great waste incident to discarding a swing bridge when an increased width of roadway is required is saved by using a rolling-lift bridge in the first instance. The substructure of a rolling-lift bridge requires less material and costs less than the substructure of a swing bridge with its necessary protection pier. The first cost and the large cost of maintenance of the protection pier of a swing bridge is entirely saved with a rolling-lift bridge.

The best evidence of the superiority of the rolling-lift bridge over the swing bridge is the fact that the most able and progressive railroad and municipal engineers appreciate the many advantages of this type of bridge and have been and are discarding and replacing their swing bridges with rolling-lift bridges. Very respectfully yours,

Albert H. Scherzer,
President The Scherzer Rolling Lift Bridge Co.
1616 Monadnock Block, Chicago, Ill., Feb. 6, 1902.

Sir: In regard to the discussion over the new Genesee Ave. bridge at Saginaw, Mich., would state: The city expects to let the work in a single contract, they have a few general specifications as to superstructure, depth of river, etc., nothing in regard to the nature of subsoil or borings to guide the engineer in making the plans. They expect each bidder to spend about $200 to $500 in making survey, preparing plans and specifications, only one of whom would ever be paid for this work. There is not even a guarantee that the form of bridge submitted by the bidder will be considered for an instant.

The city of Saginaw should employ a competent bridge engineer to make borings, soundings, profiles and substructure plans, also to fix upon the type of bridge and the length and character of the approaches. Bids should then be asked on the substructure and superstructure separately, and then many reputable companies would be glad to submit detail plans of superstructure, as it would be right in line with their work and they can do so without excessive expense. There are many bridge firms who can obtain all the work they desire at the present time in superstructure alone, and do not care to figure on substructure, others will not figure where the substructure and general conditions existing are an unknown quantity, all these features reduce the number of bidders to a few, and then the lowest figure is based on a guess or inside knowledge of the facts. A consulting engineer, if he is the right sort, could put matters in such shape that the city can obtain the benefits of competition on both substructure and superstructure and could easily save his commission many times over for the city.

A bascule bridge is a very fine thing; it was designed to meet certain conditions where a swing bridge would damage thousands of dollars worth of property, and where all available space was required both for dock purposes and width of river, and where the bridge was to be opened frequently. But when the bridge is to be opened only a few times a day, the river 800 ft. wide, and but a small clearance, do the conditions require a bascule bridge? There are people in Saginaw who have seen a bascule bridge, many have heard of them and admire them and are ready and willing to spend from $20,000 to $30,000 extra in order to get one, but are they not like the man, who after hearing all the good points about Sapolio, insisted upon purchasing a bar for use as a shaving soap, and after one or two trials found that the relative conditions as to their utility were somewhat different? Very respectfully,

Edgar A. Rossiter,
Engr. Dep't. of Track Elevation.
Chicago, Feb. 6, 1902.

The Safety of the Brooklyn Bridge.

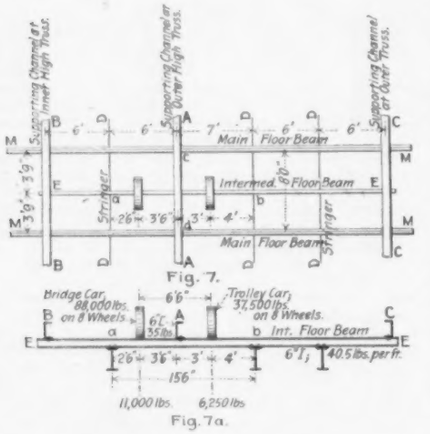
Sir: In the reply of Messrs. Duryea and Mayer in your issue of Jan. 30 to my review of their report on the Brooklyn Bridge, the main issue, namely, the existence or non-existence of excessive secondary stresses in the cables is barely touched upon, and the examiners avoid even the least mention of the six arguments which I have advanced to prove that their calculation of secondary stresses was based on wrong assumptions and on a faulty theory.

The whole reply is confined principally to the supposed discovery of some flaws in my calculations, which, if true, would merely modify the results of my calculations without proving the correctness of the examiners' theories. It can be shown that the points in my review which were criticised in the recent reply of Messrs. Duryea and Mayer are either correct or are in error by too small an amount to materially affect the correctness of my results.

(1) Flexure of the Slipjoint Plates.—The examiners claim that I should have assumed a bending force of 72 tons in place of 36 tons, as I did. I think the examiners are mistaken herein, but even if they are correct, it would increase the angle of the stiffening truss in the center of the span so little, that the results, as given in my review, will practically remain the same. I do not agree with the examiners that the truss chords can bend individually, except the ends which project over the truss-posts on each side of the center. These ends are not over 6 ins. in length, hence their elastic flexure can be neglected, being too small to deserve consideration.

(2) Trains Running at a Speed of 40 Miles per Hour.—This statement was made by Mr. Martin, and refers to the electric trains running during the night.

(3) Worthlessness of my Calculation on Account of my "Assuming" a Circle for the Cable Curve in the Center of Main Span.—This is a criticism which the examiners should not have made, because they know or ought to know that I did not base my calculations on such an assumption. The curvature of the cables is determined by the relative position of three points of the curve. I calculated the ordinates of these three points for two different conditions of loading, without any other assumption except the distribution of the loads, by a method which practice has proved to be correct. After having determined the relative positions of three points, I connected them by a circle, merely for comparing the degree of curvature of the cable under two different conditions, and for conveniently calculating the length of the curves, in order to find the stretch of the wires and, therewith, the secondary stresses. In all mathematical problems it



is customary to measure the degree of curvature by a circle of a certain radius. I have shown that in one case the cable curve corresponds to a circle of 2,334 ft. radius and in the other case to one of 684 ft. radius. The relative lengths of the two curves, whether they be circles, parabolas, or anything else, will be precisely the same in all cases, hence my assumption of circles, whether they be the true curves or not, has no influence on the correctness of the result. My "elaborate" calculation is, therefore, not valueless on that account!

(4) Absurdity of the Statement of Making a Cable Stronger by Making it Weaker.—The examiners corroborate this statement with their example of a small stick, tied to a large hinged stick, which must bend to the angle of the hinged stick. The thicker the small stick is, the sooner it will break in its effort to bend to that angle. This illustration merely turns the matter around and shows that the stronger a cable is made (meaning the larger its diameter is made), the weaker it will be. The examiners correctly remark that this is a fact and not an absurdity. The apparent absurdity is not in my calling it so, but it is in the theory of the examiners, which does not take the thickness or stiffness of the cables into account. Referring to the example of the two sticks: if the small stick is tolerably stiff it will refuse to follow the angle of the hinged stick, just as a large cable will not be governed by a hinged truss, but will form its own curvature in accordance with its stiffness and, therefore, a large cable will be stronger than a small cable. If it were not so, and if the examiners' theory were correct, it would be possible to break a wrapped wire cable by merely making it large, say 5 to 6 ft. in diameter, by building it in winter, by hanging from it a rigid hinged truss and by exposing it to the rays of a summer sun. The secondary stresses in such a case would exceed the ultimate strength of the wires and the latter would break!

(5) Misquotations.—There is but one misquotation in my review: my incorrectly stating the conditions under which the examiners calculated the bending stresses of the towers. This was an oversight, and is of no significance, because I did not challenge the correctness of the examiners' results, but based my arguments for the safety of the towers on these same results.

(6) Horizontal Deflection of Floor.—The examiners have discovered, herein, a true error in my review, but the error is only in the statement and not in the calculation. Under a wind pressure of 30 lbs. per sq. ft. the floor will deflect 1.2 ft. and the cables 1.5 ft., as stated before. By straining the storm cables and underfloor stays, as they were originally designed, up to one-half of their breaking strength, I should have said that under this assumption they were alone able to withstand the whole wind pressure and not that such stresses occur at a deflection of 1.2 ft. However, the absolute amount of side deflection is of no particular interest, and the object of quoting the above-given figures was to show that cables and floor swing sideways nearly alike and that, therefore, no appreciable wind pressures have to be transferred from one to the other.

(7) Proposed Alterations.—The examiners claim that I had credited them with a bad plan which is not theirs but my own. This assertion is not in accordance with the facts. The examiners will surely not deny that they proposed removing all suspenders from the stay systems and anchoring the land cables to the ground! This is not my plan, but it is the one on which I based my calculations for showing the error of the examiners' propositions. I calculated, first, the tensions in river and land cables, together with the force necessary for anchoring the latter to the ground, all under the assumption of mean temperature. Then I calculated the same items for about + 5° F. and under the supposition that the saddles be fixed. The latter assumption is probably what the examiners call a bad plan, but there is no reason for not making such an assumption. The saddles may become fixed later on, even if they are made free, just as they are fixed now, though they were once movable. The examiners did certainly not express themselves very clearly as to their intentions with the saddles, as the following quotation will show:

> The fixed saddles at top of towers produce increased and not accurately known bending stresses in center pillars of towers. If the saddles are made free, largely increased stresses will occur in stay system; it is unable to carry them and should, therefore, be strengthened. This strengthening of stay system increases bending stresses in towers.

It appears from this quotation that increased bending stresses in the towers will occur in either case, whether the saddles be fixed or free!

If the saddles are movable without friction the calculation of stresses, as given in my review, will be more favorable to the examiners' plan. The primary stress in one land cable at a temperature of + 5° F. will be reduced from 38,300 lbs. per sq. in. to about 33,000 lbs., and the holding-down force from 78 tons to about 67 tons. Assuming, also, that the examiners' proposition of removing the wrapping from the cables will avoid all secondary stresses except those of the individual wires, which will amount to 7,500 lbs. per sq. in. (if 2,000 lbs. is the correct bending stress for a concentrated load of 18 tons), the total stress from dead load in one land cable will be 40,500 lbs. per sq. in., while it is only 33,000 lbs. under the present conditions and when the cables are not anchored down.

Therefore, under the most favorable conditions, the examiners' plan of reconstruction will be of no advantage, and, actually, it would decrease the safety of the bridge.

(8) Strength of Supporting Channels.—In censuring this part of my review the examiners are more severe and less justified than in anything else. I have mentioned in my review that the floor construction, as customary in truss bridges, would also answer the conditions of a suspension bridge, but the problem at the Brooklyn Bridge was to construct a floor strong and safe enough with the minimum of weight. The question, therefore, is: What are the stresses in the different parts of the floor system as it is now, and not as it might be or as it is somewhere else. I selected, as example, the supporting channel, and I have given the calculation in detail. The examiners claim that I used an "erroneous" method (without explaining why it is erroneous), and that I neglected the weight of the second wheel on the same axle. Let us see whether these assertions are correct.

Referring again to Fig. 7 and Fig. 7A, the reader will notice that, for a standard wheel gage, the two wheels, which I neglected, come on the far side of stringers (b) and (a), hence they exercise no pressure on the intermediate floor beams and on the supporting channel under consideration, and they were rightfully neglected. While I remarked that the intermediate floor beams and supporting channels are continuous over a number of openings, I did not calculate them on the theory of continuous girders, but I said distinctly that I considered them as single span girders with fixed ends. If beams firmly riveted to their supports, like those in question, are not girders with fixed ends, I should like to know what else they are! My calculation was, therefore, not based on a "new principle," but merely on the old, common rule as given in every text book for determining the deflection and stresses in a girder with fixed ends.

The examiners tell me that I should have used 8,100 lbs. for the weight of a trolley-car wheel, in place of 6,250 lbs. I will, cheerfully, make this correction, and by substituting the new figure in the formula expressing the fiber stress we find for the latter: S = 17,950 lbs., which is more than 15,800, as found before, but which is still a long way below 34,000 lbs., the figure given by the examiners. I submit this question again to the profession for judging on which side the unreliability and imputed "utter carelessness" in calculation must be fixed!

Since this correspondence has been going on, we read almost daily of a Brooklyn Bridge "crush," when overcrowded cars cover both roadways of the bridge, but, so far, none of these supporting channels has failed or even shown a sign of failing. Is this fact, in combination with the circumstance that the present floor system has been in service for nearly 19 years, not a tolerably good testimony for the strength of the floor and against the existence of excessive stresses as asserted by the examiners?

I have myself repeatedly urged the advisability of a thorough inspection and of certain suggested improvements in the Brooklyn Bridge in order that accidents similar to those of last summer and those of three years ago may not recur, but I have proved in my review of the examiners' report that their danger-cry was unfounded and that the bridge, as it was originally designed and built, is sound in every particular. The examiners' reply to my review has failed to shake or to alter this fact.

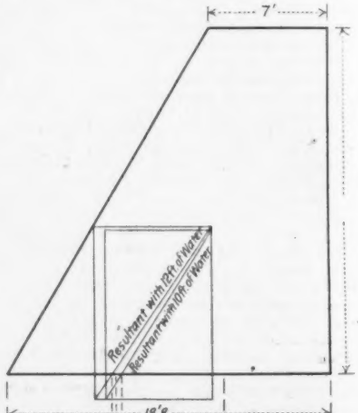
New York, Feb. 2, 1902. Wilhelm Hildenbrand.

(The dearth of literature on the subject of suspension bridge design and the experience in this field of the engineers who have contributed to the discussion in our columns have caused us to be unusually liberal in granting space for its conduct. The subject has now been thoroughly gone over, however, and both sides having been fairly and fully presented, we shall let the above letter close the discussion.—Ed.)

Further Discussion of the Upper Tallassee Dam, Across the Tallapoosa River, Ala.

Sir: From the comments upon my criticism of the Upper Tallassee Dam by the engineers of the International Hydraulic Co., in Engineering News of Jan. 16, 1902, they appear to think it was made from an entirely theoretical standpoint. In answer to one of their queries, I would say that I have had occasion to remove large stone from a rubble wall, and was not surprised at the great number of voids, for the simple reason that they were not visible. I refer to the lock walls which occupied the site of the present power house of the Willson Aluminum Co., Holcomb Rock, Va. (Eng. News, April 14, 1898). In removing these walls, containing some 1,500 cu. yds., it was necessary to resort to drilling and dynamite. There was not a crevice in which the point of a bar could be inserted, and the cost to the contractor of taking the walls down was as great as though the stone had been taken out of a quarry. They were examples of what good work and careful inspection can accomplish.

Applying some "elementary mathematics" to the question of weight, I am unable to see that 10% can be added to the weight of a rubble wall by any method of grouting. A cubic yard of gneiss will weigh approximately 4,540 lbs. A rubble wall carefully laid with full mortar beds and joints will require about 0.3 cu. yd. of mortar, which, if composed of 1 part of natural cement and 2 parts of sand, will weigh approximately 940 lbs. In a yard of rubble in which there is 0.3 yd. of mortar there must be 0.7 yd. of stone, or should be, and by elementary mathematics 1 cu. yd. of rubble will weigh 4,118 lbs., or 152 lbs. per cu. ft. If 10% is added, then the weight must be 167 lbs. per cu. ft., or within 1 lb. of the weight of 1 cu. ft. of solid gneiss. That is why I don't believe it.



Graphical Study of the Upper Tallassee Dam.

If the 152 lbs. represents the weight after it has been increased 10%, then by a similar computation the weight would be less than 139 lbs. if built with full mortar beds and joints; and I don't believe that either.

The error as to height to which the wall was built up before grouting is not mine. In the published article the sentence reads: "After this material was built up to a height of 5 or 6 ft. . . ."

Attention was called to the use of concrete alone for the rollway of dams, it is quite true, but its efficiency and suitability for the purpose is a much discussed question among engineers. Those which I have seen have not given unqualified satisfaction, and their heights do not much exceed 20 ft. Where they are built with a curved lower face, the concrete becomes extremely rough from the action of the water, and requires frequent refacing with cement mortar. They are also liable to develop cracks, and one I have in mind which was strengthened by the insertion of steel bars as the concrete was built up, has developed numerous cracks, which presumably extend

clear through the dam. The same is true of a number of concrete bulkheads.

What changes are made in specifications as experience suggests, is unquestionably true; but such recent examples of masonry construction as the Holyoke Dam, the Austin Dam (a section of which moved bodily and was not disintegrated before the rupture), the St. Mary's Canal Locks, built by the U. S. Goverment at Sault Ste. Marie, and Section No. 5 of the Boston Water Supply (containing about 2,000 cu. yds. of rubble masonry), prohibit the use of mortar and require horizontal and vertical bonding.

The specifications covering the manner in which the stone shall be laid, how the mortar shall be used, its composition, etc., can be written as well in one place as another; none of these things would be determined by the character of the stone.

It is asked why some attention was not given to the stability of the dam, whether or not it is of ample section to prevent sliding or overturning. A first glance at the section of the dam as published in Engineering News would give the impression that it is none too heavy to withstand a flood of 10 ft. over the crest, and this impression is strengthened if we apply some more mathematics to it, especially if we use the equations of Mr. J. P. Frizell to determine center of pressure and total pressure on the up-stream face.

The accompanying diagram shows the position of the resultants of the pressures with 10 ft. and 12 ft. of water above the crest.

Mr. Frizell's equations are as follows:

$$\text{Center of pressure} = \frac{H}{3}\left(1 + \frac{h}{H+2h}\right).$$

$$\text{Total pressure} = 62.5\ H\left(\frac{H}{2} + h\right).$$

In which H = height of dam, and h = depth of water on the crest. The masonry is assumed to weigh 150 lbs. per cu. ft.—not 165 lbs.

It will be observed that with 10 ft. of water on the dam the resultant falls dangerously near the outer third of the base, while with 12 ft. it falls 0.23 ft. beyond the middle third, thereby putting the masonry on the up-stream face in tension. The section to which the diagram applies is the first 20 ft. from the crest down, and I have neglected the slight reduction in masonry due to the curved corner and slope of the top, the section being treated as a trapezoid.

While the S. Morgan-Smith Co. furnished the turbines for the Montgomery plant, they were not responsible for any other part of the work; therefore it was not necessary that they or myself should obtain information about the construction of the dam. Had they been responsible for its design and construction, I am free to say that both would have been materially different.

That "the proof of the pudding is in the eating" is well established in this instance, the dam went out, and only two days afterwards my criticism was written, in which it was intimated there was no particular reason why it should not.

I quite agree with Mr. John W. Hays (Eng. News, Jan. 23, 1902) that it is difficult to get masons to lay up a water-tight wall, if left to their own devices; but I have not found it impossible if proper inspection is given to the work. The inspector, however, must know his business: a farm hand who never saw such work built cannot be expected to know how it should be done. The loss caused by a failure of a high dam may be, and usually is, much greater than the extra cost required to build it properly in the first place, and if capital is unwilling to incur the expense required to so properly build it the work should not be undertaken.

The semi-rock fill dam (Eng. News, Jan 16, 1902; also see Feb. 6.—Ed.) was correctly illustrated, as the following extract from a letter from Mr. W. A. Carlisle, Chief Engineer North Georgia Electric Co., verifies:

North Georgia Electric Co.
Engineer's Office.
Gainesville, Ga., Jan. 26, 1902.

Mr. J. C. Temple, Germantown, Philadelphia.

Dear sir: You can rest assured that the dam is exactly as the cut in Engineering News represents it. . . . I am sure I saw the construction as I represented it to you. Anyone doubting it, just send them to . . . and they will see it as I did. Yours truly,
(Signed.) W. A. Carlisle.

It was not I who got the cart before the horse, but the party who hitched them up. Yours truly,
John C. Temple.
200 West Walnut Lane,
Germantown, Philadelphia, Feb. 1, 1902.

Concerning Theses in Engineering Schools.

Sir: In the regular course of our technical schools a large part of the fourth year is taken up with the preparation of a thesis. As a general thing, the subject is one which is far beyond the knowledge and experience of the student. He, however, flounders along and hands in something which he thinks about perfect. What is the result? It unduly elevates the student's opinion of himself, and the imperfect treatise injures the subject and also the profession. In other words, a large part of his fourth year has been worse than wasted.

Anyone who employs young graduates appreciates this. The graduate writes a letter of application, stating he has just taken his degree, having written a thesis on so and so—a subject that he will not be prepared to tackle until he has had many years of practical experience. Yet it is very evident that he feels himself thoroughly familiar with the subject, and can step right in and do anything desired of him, giving the older fellows points on modern theory and practice. Before a student can be of any practical value he has got to get this idea of his superiority out of his head—and some of them have great tenacity. Then he must start at the bottom and work his way up as he familiarizes himself with the practical details of the work and learns to apply his theory.

It is far better for the technical schools not to attempt to teach practice. Let them rather concentrate their efforts upon the theory, as they have not the facilities to teach practice, and as it is changed before it is taught. There is more than enough theory to occupy their time, and the majority will never learn it if not taught at the schools. They cannot get too much. At the end of the course, upon passing satisfactory examinations, give the graduate a scientific degree. For they are not engineers, and no school can ever make them such. When they have had at least five years' experience with practical work, and upon writing a satisfactory dissertation on some theoretical or practical engineering subject, then let them receive their engineering degrees.

Yours truly, Alex. Rice McKim.
106 E. 23d St., New York, Feb. 3, 1902.

IN CLASSIFICATION YARDS at terminals coal cars are usually classified according to destination, the same as other freight. In the rearrangement of tracks at the Jersey City terminal of the Erie Ry., however, it is proposed to have the classification of coal done by sizes rather than by destination. The anthracite coal arriving at that station is of about the same quality, no matter from which mines it is received, and by unloading as above suggested the amount of switching will be materially reduced.

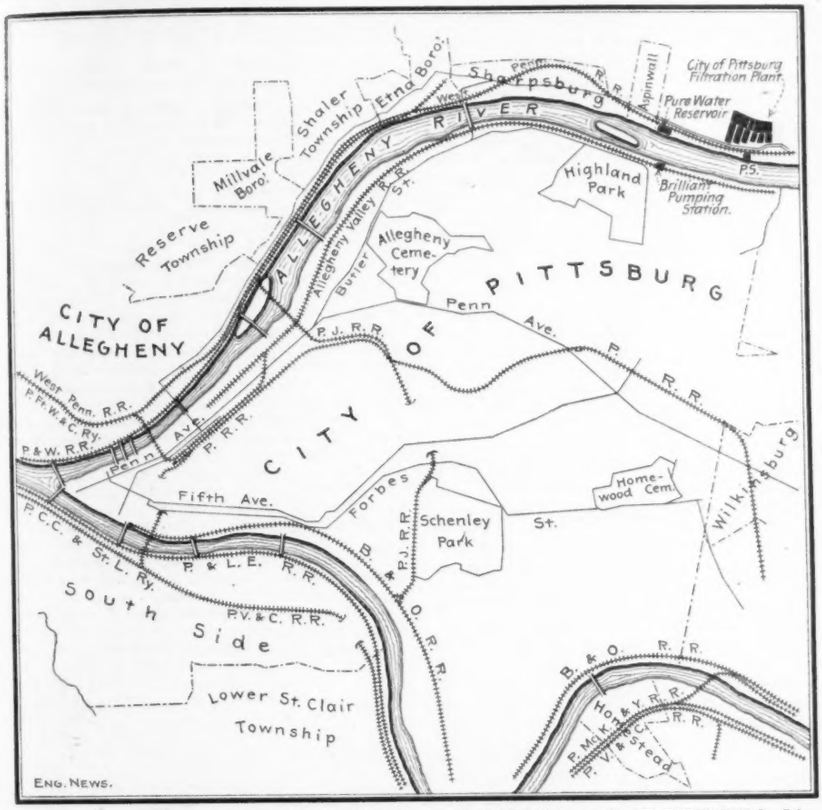


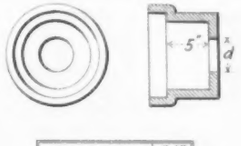
FIG. 1. MAP SHOWING LOCATION OF WATER PURIFICATION PLANT AT PITTSBURG, PA.

SETTLING BASINS AND SLOW SAND FILTER BEDS FOR PITTSBURG, PA.

(With two-page plate.)

After the lapse of nearly six years since the appointment of the Pittsburg Filtration Commission, and over three years since the commission made its notable report on its water purification experiments, bids are to be received at Pittsburg on Feb. 24 for constructing sedimentation basins and a slow sand filtration plant. The commission in question organized on July 6, 1896, with Mr. Robert Pitcairn as chairman, and subsequently engaged Mr. Allen Hazen, M. Am. Soc. C. E., of New York city, as Consulting Engineer, and Mr. Morris Knowles, Assoc. M. Am. Soc. C. E., then of Lawrence, Mass., as Resident Engineer. Mr. Walther Riddle, of Pittsburg, was engaged as Chemist, and Mr. Wm. R. Copeland, also of Lawrence, as Bacteriologist. The commission then entered upon a series of experiments with both slow sand and mechanical filtration. It also secured a report from Prof. Wm. T. Sedgwick, of Boston, on "The Sources of Typhoid Fever in Pittsburg," and another report from Mr. Emil Kuichling, M. Am. Soc. C. E., of Rochester, N. Y., on "A Gravity Water Supply from Indian Creek." The final conclusions of the committee, as stated in its report (see Eng. News, Feb. 23, 1899), were in favor of sedimentation and slow sand filtration.

The labors of the Filtration Commission terminated with the submission of its report. Since that date there have been so many political upheavals in Pittsburg that its citizens may consider themselves fortunate indeed that the general plans are not only to be carried out, but that their development has been continued by Mr. Hazen from the outset. It is also a pleasure to note that Mr. Knowles was again called into service a few months ago as Resident Engineer of the Bureau of Filtration. Earlier in the development of the plans Mr. W. F. Miller was Resident Engineer. The Bureau of Filtration is under the control of the Director of Public Works. That office is now filled by Dr. J. Guy McCandless, who was preceded by Mr. Edw. M. Bigelow, M. Am. Soc. C. E. Mr. Geo. W. Wilson has also held the office for a time since the filtration plans were begun.



No. of Pieces	"d"
100	4.5
150	5.0
200	6.0

Fig. 9a. Compensating Orifice for Filter Underdrains.

The illustrations on our double-page plate and in the text of this article convey a very good idea of both the general plan and the major details of the works proposed at Pittsburg. The main features are the 50,000,000-gallon sedimentation basin, in three divisions, and the 25 open filter beds, each with an available area of one acre. Among the special features are the regulation of the beds in groups from five regulator houses; the underdrainage system, with its fric-

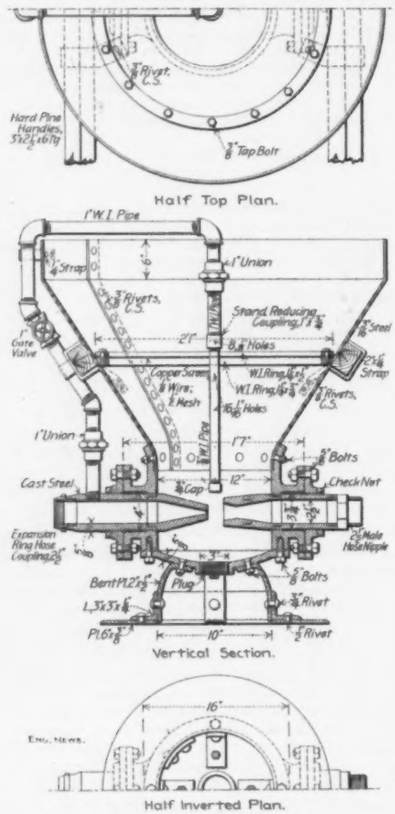


Fig. 10. Portable Sand Ejector.

tion compensating orifices; the sand washers, with supplementary portable sand ejectors to receive the dirty sand as scraped from the beds; the track system for transporting sand, which includes also portable sections for use on the surface of the beds; and the ice chutes for clearing the beds from ice in winter.

The chief objects of the Pittsburg water purification plant are to remove turbidity and bacteria. The Allegheny River, from which the supply will continue to be taken, carries a large amount of sediment at times, is rarely if ever satisfactory in appearance, and is dangerously polluted.

Fig. 1 is a general map, showing the location of the settling basins and filter beds in relation to the city. The map also shows the proposed new pumping station to supply the settling basins, and the clear water reservoir, both of which, like the conduit to the present main pumping station, will be included in future contracts.

Fig. 2, on the double-page plate, may be termed a key map to the settling basins, filters and various pipe systems. The 72-in. steel force main leads from the pump house to the settling reservoirs, Fig. 3, and discharges through outlets in the middle of a central receiving basin. From this central basin numerous outlets lead, on either hand, to the large settling basins on each side. At the other end of these basins the clarified water is drawn off through numerous outlets. It then passes to three pressure controller houses, as shown, and thence to the several beds. The collecting underdrains center in five regulator houses, from which the various operations of each bed in as many groups may be observed and controlled. From these regulator houses the water goes to the clear water main, 66 ins. in diameter after the last connection, and through it to the clear water reservoir.

Fig. 3 shows the plan and a number of sections of the sedimentation basins. The specifications provide that the embankments shall be constructed of alternate 3-in. layers of the best clayey and gravelly material found in excavation, thoroughly mixed by means of a harrow or otherwise, and then rolled in 6-in. layers, not less than six times, with a 10-ton roller. It will be noticed, Fig. 3, that the inner slopes of these embankments are lined with concrete below and paved with stone blocks above. The stone blocks rest on broken stone, beneath which, as also the pavement, there is a layer of puddle. The puddle must consist of 1 part of plastic clay and 2 parts of sandy gravel mixed in a pug mill.

An interesting feature of the work is the manner of constructing the concrete filter walls and floors, shown by Fig. 4. The walls are formed of huge blocks, tongued and grooved. The floors are to be in squares of about 50 sq. ft. The metal forms used for this purpose will extend only partly through the concrete, and the spaces thus left are to be "entirely filled with an asphalt mixture remaining soft at freezing temperature."

American Portland cement is to be used throughout. The concrete is to be prepared in cubical machine mixers. The blocks for the walls are to be not less than 10 nor more than 20 ft. long, "and shall in general be of a uniform length to be selected by the contractor within these limits." The proportions shall be 1 volume of cement to 3 of sand and 5 of ballast. This applies to the floors, also. The upper 2 ft. of the inside walls, the tops of the walls and the top of the floor will consist of mortar composed of 1 volume of cement and 1½ volumes of sand. The wall surface finish will be 1 in. and the floor finish ½-in. thick. All wall joints which open more than ¼-in. before the work is accepted must be calked with jute and grouted with neat cement. All wall corners are to be monolithic. If the Director of Public Works so orders, stone masonry may be substituted for concrete in the upper 3 ft. of the filter walls.

The pressure controller valves are in three sets. The set in house No. 1 connects with a 36-in pipe, and has two pairs of openings; No. 2 connects with a 42-in. pipe, and has three pairs of openings; No. 3 connects with a 48-in. pipe, and has four pairs of openings. The latter is shown in plan and section by Fig. 5, while Fig. 6 shows the controller valve. The valve boxes and stilling boxes are made from riveted steel plates. The floats are of copper.

The general design of the regulator houses and of the indicator apparatus is shown by Figs. 7 and 8, respectively. The water from each filter bed passes through a 20-in. Venturi meter, with a 9-in. throat, before it reaches the regulator house. These meters are to have bronze throats and piezometer pressure connections. In the wall of each filter bed there will be a brass tube, Fig. 7, with strainer connections. These tubes, and the throats and one end of the Venturi meters, will be connected with the regulator houses by means of ¾-in. lead-lined iron pipes. These pipes will terminate in three-way brass cocks, tapped into caps on the bottom of the 6-in. wrought-iron float tubes shown in Fig. 8. The floats will be of seamless copper, attached to No. 25 B. & S. gage phosphor bronze wire, or its equal. The wires will run over pulleys and be attached to indicators or movable scales, constructed of brass and lettered with enamel.

The underdrainage, or pure water collecting system, is shown for a single bed by Fig. 9. The main or central collecting pipe in each filter is to be laid with tight joints, formed by first inserting a small jute gasket, saturated with neat Portland cement, and then filling the remaining space with 1 to 1 cement mortar. The main drain is to be surrounded with gravel concrete, made as water tight as possible, carried up until it forms a part of the filter floor. After the central drain is laid a man must go through it and "completely fill each joint with neat Portland cement," leaving it flush with the interior of the pipe.

The branch collectors, shown in detail in Fig. 9, are to have open joints and are to be laid with "a space of about ¾-in. between the barrels of the pipes, for the admission of water." The lower part of the bells are to be cut away, as shown, so the drains will lay close to the filter floor. Fig. 9a, in the text, and one of the details included in Fig. 9, show the compensating orifices, designed to give a uniform frictional resistance throughout the bed. These orifices are described in the specifications as follows:

At the lower end of some of the lateral drains [illegible] pensating orifices shall be placed as outlets to the lat[illegible] These compensating orifices shall be made accurate[illegible] the dimensions shown and variations in the diameter[illegible] of the orifices shall in no case exceed ⅛-in. Four [illegible] orifices with diameters of 4½ ins. shall be used in [illegible] filter, six orifices with diameters of 5 ins., and eight [illegible] fices with diameters of 6 ins.

The specifications for filter gravel and sand, with some omissions, are as follows:

FILTER GRAVEL.—On the floors of the filters and surrounding the underdrains shall be placed gravel or broken stone having an average depth of about 1.1 ft.

Instructions will be given by the Director as to the exact arrangement and positions of the various layers when the gravel or stone commences to be received upon the ground, the arrangement will be approximately as follows:

The lower 7 to 9 ins. shall consist of broken stone or gravel which will remain upon a screen with a mesh of 1 in., and has very few stones over 2 ins. in diameter. Above this shall be placed 2½ ins. of broken stone or gravel which has passed a screen with a mesh of 1 in. and which remains upon a screen with a mesh of ⅝ in. Above this shall be placed 2½ ins. of broken stone or gravel which has passed a screen with a mesh of ⅝-in. and which is coarser than the ordinary sand and free from fine material. . . . .

The materials for all the layers shall be hard, durable stone broken and screened to the proper sizes, or gravel screened from river deposits or banks of a sandy nature. Gravel screened from hardpan or clayey material cannot be sufficiently cleaned. The gravel shall not contain more than a very small amount of shale or limestone. Broken stone shall not be of or contain limestone, sandstone or shale. The gravel or broken stone shall be washed entirely free from foreign and fine materials, so that water passing through it or agitated in contact with it will remain substantially clean. . . . .

Gravel shall not be placed within 6 ft. of the inlet chambers nor within 2 ft. of the outside or crosswalls, these spaces being reserved for filling with sand. . . . .

FILTER SAND.—Filter sand shall be clean Allegheny

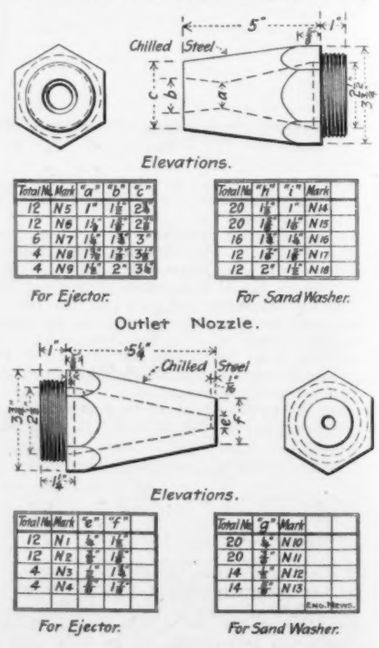


Fig. 10a. Details of Inlet and Outlet Nozzles.

River sand. It shall be entirely free from clay, dirt, coal or organic impurities and shall, if necessary, be washed to remove such materials from it.

The diameters of the sand grains shall be computed as the diameters of spheres of equal volumes. The grains shall have the following diameters:

Not more than 0.5% by weight shall be less than 0.13 mm.; not more than 7% less than 0.26 mm. At least 7% by weight shall be less than 0.34 mm.; at least 70% less than 0.83, and at least 90% less than 2.1 mm.

...particles shall be more than 5 mm. in diameter, and the sand shall be passed through screens or sieves of such mesh as to stop all such particles, and no screen or sieve shall be used containing at any point holes or openings allowing grains larger than the above to pass.

...filter sand shall not contain more than 1% of lime and magnesia, taken together and calculated as carbonates.

...filter sand shall be deposited in the filters in three layers of approximately equal depth. It shall not be dropped from a height into final position nor otherwise unduly compacted. The first two layers may be filled to approximate depths, only, and the surfaces need not be smoothed. The final layer shall be brought to a true and even grade and the surface left smooth and uniform, and such allowance for settlement shall be made as the Director shall direct.

The track system for moving sand is shown in plan and detail by Fig. 13. The track to be used in the filter, as already stated, will be portable. The sand cars will be of metal, of ½ cu. yd. capacity.

Ice chutes, to facilitate the removal of ice from the beds in winter, are shown by Fig. 14.

The laboratory building, combined with Regulator House No. 2, will have a basement and two floors. The upper floor, Fig. 15, will contain the chemical and bacterial laboratories. The building will also house a hot water heating plant, an ice making machine with a capacity of 500 lbs. per 24 hours, bath room and other conveniences, a dark room and a fireproof vault.

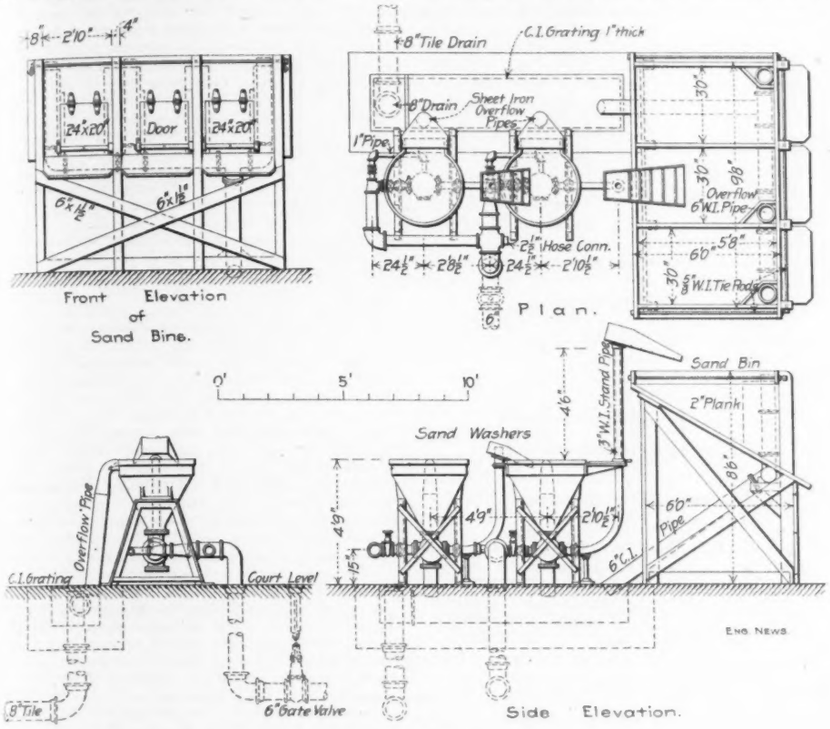


FIG. 11. PLAN AND ELEVATIONS OF SAND WASHERS AND BINS.

No details of this filter plant have been worked out with more care than those for cleaning and renewing the filter beds. These include conveying the sand to and from the washers, as well as the washers themselves. The dirty sand will be transported through pipes by means of water under pressure, and the clean sand will be returned to the beds upon cars running on fixed and portable track, the latter on the surface of the beds. A system of piping along the filter walls, with hose connections at frequent intervals, combined with a portable sand ejector, will make it possible to deliver the dirty sand from the various beds to the sand washers with a minimum of labor. Fig. 10, in the text, shows the portable sand ejector, Fig. 11 a plan and elevation of one of the 14 sand washers and bins, and Fig. 12 the details of the sand washers. Fig. 10a shows the inlet and outlet nozzles for both the ejectors and washers, which are made of hardened steel and finished all over. It will be noticed that the nozzles are all horizontal, and that a branch pipe, provided with a valve for adjusting the flow, connects the supply main of the sand washers with the globe casting in which the nozzles are placed. This is designed to supply all the water taken into the ejector so that the sand will be entirely separated from the dirty water which accompanies it from the preceding hopper, instead of simply diluting it as in previous designs. In the sand ejector a somewhat similar pipe connection is carried to the top of the hopper and continued down through its center nearly to the nozzles. This pipe is open at its lower extremity and perforated horizontally just above the screen.

DRAINAGE IMPROVEMENT BY DREDGING.*

By E. E. Watts.†

A demand for lands of greater fertility than that of the over-farmed high lands has turned attention to the alluvial basins of rivers and large creeks, the channels of which have been obliterated, by deposits, in the lower levels of the basin. The soil is of great fertility and is covered with timber of many varieties, of greater or less value. Large areas of open prairie marsh lands are found generally in the basins of sluggish flowing streams, and are usually traversed by ridges, the soil of which is of less fertility than that of the adjacent marsh. Both the timbered and the prairie wet lands have, until recently, been regarded as valueless (except for the small value of the timber) on account of the entire absence of drainage.

The problems presented to the engineer by these conditions are as follows: (1) To reopen the channels of existing water courses (which have been rendered insufficient) to a size sufficient to dispose of the drainage of the entire water shed. (2) To provide a system of drainage for the reclamation of the wet and overflowed basins or "bottom lands" by constructing ditches or drainage canals to intercept the water coming from the high lands and conveying the same to an outlet in the main stream, and by protecting the lands of the basin from overflows of the stream traversing it, by constructing levees or dykes or by increasing the capacity of the channel of the stream. (3) To provide for cities and towns located at a distance from a large stream, a sufficient outlet for storm drainage and a means of sewage disposal by constructing artificial channels to, or increasing the capacity of natural water courses having an outlet in, a water course of sufficient channel to receive the sewage.

To meet these conditions and afford the relief sought, requires the construction of ditches or canals of large cross-section and other works of a less significant character, which are not discussed in this report. The ordinary methods of construction are not adaptable to this kind of work. The character of the excavation is usually in soil thoroughly saturated at all seasons, the lines of the improvements being located through the lowest lands which are generally covered with water the greater portion of each year. The use of teams and scrapers or the "Irishman and his spade" have been precluded both on account of the prohibitive cost and the inability to construct excepting for a very short season in each year. Resort has been had to mechanical devices and this demand for a cheap and expeditious method of drainage improvement construction has resulted in the almost universal use of some form of dredge. The advent of the dredge in drainage construction has opened vast possibilities in the reclamation of swamp and overflowed lands and the growth of this business has called upon the engineering profession for more advanced methods in the plan and design of drainage work.

After a drainage work has been projected and the legal machinery set in motion, the work of the engineer properly begins. His first work should be an extended reconnoissance of the inundated lands and the entire watershed tributary thereto. Next, carefully examine possible means of outlet. This is the most important portion of the line of the improvement. Failure to provide a proper outlet has resulted in disastrous failure of many important works. Observe this rule always: "Never locate the outlet short of the channel of the receiving water course."

A contour map of the flooded district, with 1-ft. contours, will be very convenient in projecting location. This can be prepared without considerable field work. The slopes generally will be found to be quite slight and uniform, so that levels taken at half-mile intervals upon land lines and highways crossing the district transversely, will generally suffice. A location of the lines of the improvement work having been projected upon the contour map, the location surveys are then made. The work of location must necessarily proceed slowly. Care should be taken to fit the line the most advantageously to the ground.

The matter of alinement has generally been considered a mere incident in the location and, as a result, many works have been rendered less efficient by the construction of crooked, tortuous channels, or channels constructed along land lines which change direction only with a right turn, thereby increasing the friction of the flow and lessening the capacity of the channel. The same care and judgment and the same standards ought to govern the location of a line of drainage improvement that would be exercised in a high-class railway location. Much erroneous location has occurred by reason of the insistent demands of interested land owners, and the engineer, in attempting to satisfy the adverse interests, has fallen into error of bad alinement.

Having completed the location, the most important of the work of the engineer now confronts him, viz., the laying of the grade and the design of the cross-section of the channel. The question of grade is rarely one of reducing slope, but rather one of increasing, by artificial means, the natural slope, and often resolves itself into

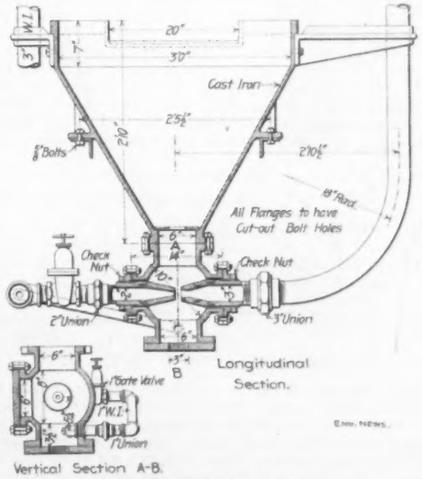


Fig. 12. Details of Sand Washers.

a question of allowable minimum slope for a given cross-section. Questions of character of soil subsoil, distribution of the natural slope and alinement enter into the consideration of this important detail. Close, careful study of these conditions with the engineer's previous experience are the requisites of success. The writer has constructed ditches seven to ten miles in length, through loam and sand on a sub-soil of fine gravel with a slope of 1 in 4,220, and the works have been in successful operation for several years. The allowable minimum in this character of soil is probably 1 in 6,000. Through black

*Abstract of a paper read at the annual meeting of the Indiana Engineering Society at Indianapolis.

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loam on a stiff clay subsoil, with a like cross-section and a similar length, another work was constructed with a slope of 1 in 1,780. The allowable minimum in this character of soil is probably 1 in 7,500. In black muck and quicksand, the writer has information of works having been attempted with a slope of 1 in 8,000, which proved a failure. In this character of soil, the allowable minimum should be 1 in 3,000. (These ratios are based upon a uniform cross-section area of 225 sq. ft.) In all cases, care should be observed to avoid abrupt breaks in the grade line at the points at which the slope flattens,

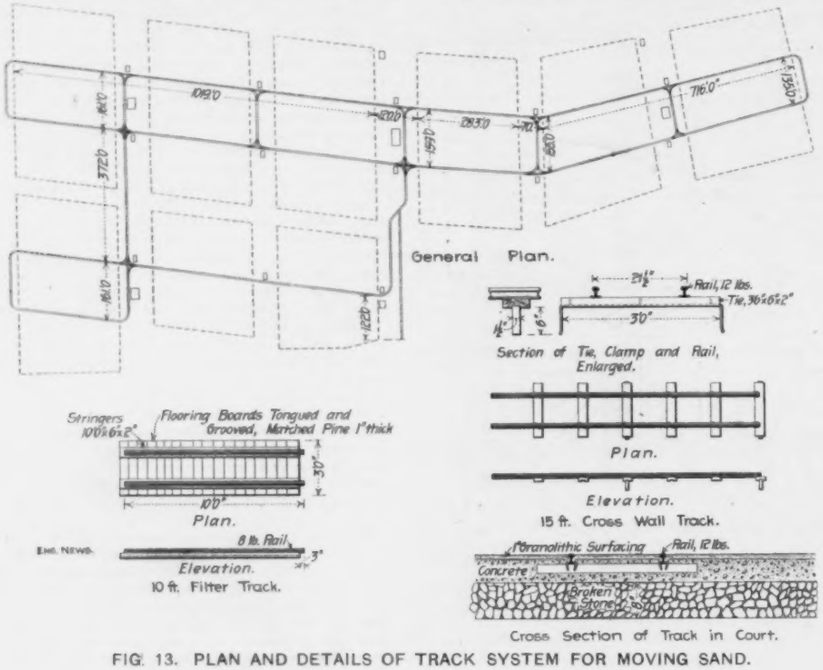

FIG. 13. PLAN AND DETAILS OF TRACK SYSTEM FOR MOVING SAND.

otherwise a bar will form in the channel just below the break, if the work be in sandy soil, and no amount of flood will remove it. Since acceleration of flow is a thing always to be desired in drainage works, the ideal grade begins with a slight slope at the source, gradually increasing until the heaviest slope is found at the outlet. An accelerated flow is productive of the greatest amount of scour, a guarantee of a minimum cost of maintenance. The cross-section of the channel should be designed with an area sufficient to provide for the water precipitated upon the watershed by the ordinarily heaviest rains. To attempt to provide for the abnormal precipitation which may occur once in a decade, will probably increase the cost to a prohibitive degree.

The construction of large drainage improvement works is usually accomplished by the use of some form of either the dipper or the elevator dredge. Elevator dredges are used only to a very limited extent, when the conditions are the most favorable. In open prairie marsh, and in soft, water-bearing soil, such machines are very successfully used,

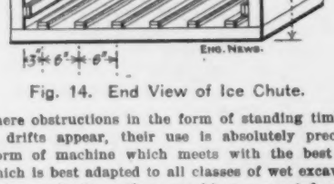

Fig. 14. End View of Ice Chute.

but where obstructions in the form of standing timber or buried drifts appear, their use is absolutely precluded. The form of machine which meets with the best favor and which is best adapted to all classes of wet excavation, is the dipper dredge. These machines are rated according to the capacity of the dipper, the usual sizes running from ¾ to 2½ cu. yds. capacity. The method of locomotion along the line of the work is either by means of anchors placed ahead of the machine and attached to a drum and cables whereby the machine is drawn forward, as in a traction dredge; or the machinery is mounted upon a large hull kept floating at the face of the work, as in the case of a floating dredge. The traction dredge is only used where necessary to begin construction at the outlet end of the ditch and keep the work free from water. The floating dredge is best adapted to the construction of large works and is started at the source of the ditch in order that the accumulated water may be held to keep the boat floating.

In order that a dredge machine may be properly operated through a timbered country, and for the more important reason of lessening the cost of maintenance, a clearing is made through the timber of a sufficient width to provide for the width of the channel, the width of the berm and spoil banks and a sufficient width on the outside of each spoil bank to permit the cleared timber to be piled clear of the berm and spoil banks so that it may be more easily fired after the drainage of the land has been accomplished. Nor should these considerations alone govern the width of the clearing. In heavy timber large ditches have become badly obstructed by reason of the carelessness of timber cutters in permitting tops of trees to be felled into and remain in the channel. If then the improvement is located through timber of a heavy, merchantable quality, the width of the clearing should be designed sufficient for the felling of the largest trees outside of the clearing, directly toward the ditch, without any portion falling into or becoming an obstruction in the channel. After the clearing has been fully made, all stumps and accessible drifts in the line of the improvement should be thoroughly loosened by the use of explosives.

The channel should be excavated to the full dimensions specified and with smooth and even base and slope of banks. It is customary to specify a slope of banks of a ratio applicable to the nature of the soil and require the construction of a cross-section of channel in the form of a trapezoid. The writer is inclined toward what may be termed the "U" form of channel. This form is that of the cross-section of least resistance to the flow and is better adapted to construction by dredge machines than any other. The bottom should conform as nearly as possible to the arc of a circle and the banks should incline at a slope not exceeding ½ to 1 for any of the soils usually encountered, excepting muck and quicksand. Muck will stand at 1½ to 1, and quicksand will probably require 3 to 1 or more. The only objection urged to the "U" form of channel is that machines do not deposit the spoil with a sufficient berm, so that any considerable scour of the banks will precipitate a large portion of the spoil into the ditch. The tendency among drainage contractors is to fit dredge machines with a boom as short as possible in order to economize in expense of operation. It is the duty of the engineer in this regard to see that the machinery is of the proper capacity in every detail and if the contractor insists upon short booms, to require that a crowding or thrusting engine be placed upon the boom in order that the dipper may be thrust out to a proper distance and the spoil properly deposited. A berm between the top of the bank of the ditch and the foot of the spoil bank, of uniform width for a given cross-section, should be required, and upon which no excavated material permitted either to be deposited or to slush or run back from the spoil bank.

Throwing up a heavy roll at the top of the bank of the ditch is a very common practice among machine operators. It is often done in order to hold back the slushy material, which has a tendency to run back into the ditch when the spoil is deposited without sufficient berm. This practice should always be prohibited, since the scour inevitably carries this roll into the ditch soon after construction. The width of the berm varies according to the cross-section of the channel and the [illegible] of the excavated material. A practice which has been favorably received is to design the width of the [illegible] equal to half the width of the base where the [illegible] do not exceed a depth of 6 ft.; for heavier cuttings the ratio should be increased one-half. In special instances, where it is deemed expedient to use the spoil bank as a levee or highway, at least two-thirds of the entire spoil may be deposited in that bank without increasing the cost. To require all of the spoil cast into one bank would very materially add to the cost of the work. The material in these spoil banks is so thoroughly saturated that no attempt should be made to trim or dress the crown and slopes until thoroughly dry, which will generally require two or three months of favorable weather. During the progress of the work of construction, the engineer should make frequent inspections. The work generally being covered with water for a considerable distance above the face of the working, affords ample opportunity to conceal defective work and unless the engineer is frequently upon the work, ragged and [illegible] slopes and base, and cribbed spoil banks will sometimes come to light to confront and reproach.

The cost of drainage improvement works constructed by dredging varies according to the size and length of the channel, the yardage to be moved, the character of the soil, the character of the growth of timber through which the improvement is located, and if in old channel, the size and nature of the buried obstructions. Contract prices vary from 5½ cts. per cu. yd. for work in open prairie marsh, without timber obstructions of any kind and averaging 60,000 cu. yds. per mile, to 10 cts. for work in heavy timber averaging 10,000 cu. yds. per mile, the cost of clearing and grubbing being included in the cost. Local conditions, such as methods and times of payment for construction work, enter largely into the determination of prices. The items of cost to the contractor include clearing and grubbing, transporting and erecting the machine at the point of commencement and dismantling at the end of the work, repairs and renewals—a heavy item of expense—fuel, incidentals and labor. All well-equipped drainage contractors provide dredge machines with electric lighting, and, with double crews, operate 20 out of the 24 hours of the day.

The cost to the land owner in drainage tax, in an average of several enterprises, embracing conditions widely differing, was $5 per acre of land affected. This may be considered a fair average, basing upon the prices at which work is usually contracted. Statistics as to the cost of maintenance of public drainage works are very meager, since the laws of nearly all the states invest the control of repairs of such works in some inferior public office, the occupant of which generally considers the matter of

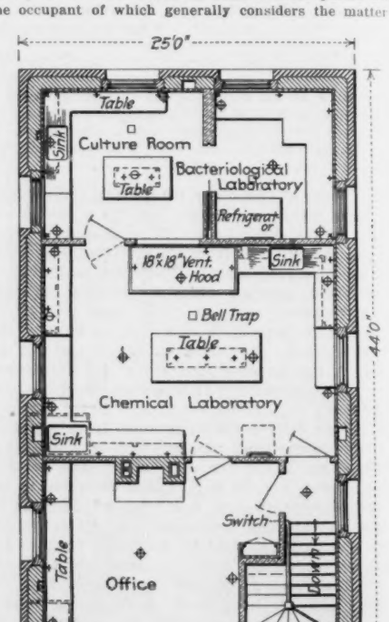

Fig. 15. Plan of Laboratory.

the record of cost of no moment. For the same reason, probably no class of public work is so badly maintained and administered. Observation leads the writer to the conclusion that a ditch of the length of ten miles, average excavation 25,000 cu. yds. per mile, in operation five years, can be maintained at a cost not to exceed $10 per mile per year. Unforeseen accidents sometimes occur and greatly increase the average annual cost, but it would be safe to venture that the average machine-constructed ditch can be maintained at that cost.